HALCON

the Power of Machine Vision

Programmer's Guide

MVTec Software GmbH

Building Vision for Business

All about using the programming language interfaces of HALCON, Version 11.0

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About This Manual

This manual describes the programming language interfaces of HALCON and shows how to use HALCON in programming languages like C++, C#, C, or Visual Basic. It contains the necessary information to understand and use the provided data structures and classes in your own programs.

We expect the reader of this manual to be familiar with the programming languages themselves and with the corresponding development tools.

The manual is divided into the following parts:

- **General Issues**
  This part contains information that is relevant for all programming interfaces, e.g., which interface to use for which programming language or how to use HALCON with parallel programming.
- **Programming With HALCON/C++**
  This part describes the HALCON's language interface to C++.
- **Programming With HALCON/C++ (legacy)**
  This part describes HALCON's legacy language interface to C++. It includes instructions to convert code using the legacy C++ interface to the new default C++ interface introduced in HALCON 11.
- **Programming With HALCON/.NET**
  This part describes HALCON's language interface to .NET programming languages (C#, Visual Basic .NET, etc.).
- **Programming With HALCON/COM**
  This part describes HALCON's language interface to languages that can handle Microsoft COM, e.g., Visual Basic 6.0 or Delphi.
- **Programming With HALCON/C**
  This part describes HALCON's language interface to C.
- **Using HDevEngine**
  This part describes how to use HDevEngine to execute HDevelop programs and procedures from a programming language.

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Part I

General Issues

Chapter 1

Basic Information About Programming with HALCON

This chapter contains basic information:

- which HALCON interface to use for which programming language (section 1.1)
- the available platform-specific HALCON versions, e.g., 32-bit or 64-bit, SSE2-optimized, etc. (section 1.2)

1.1 Which HALCON Interface to Use

Since the introduction of HALCON/.NET, for many programming languages you can now use more than one interface. Table 1.1 guides you through these possibilities.

recommendation			alternative(s)
C	→	HALCON/C	
C++ (unmanaged)	→	HALCON/C++	HALCON/COM
C++ (managed)	→	HALCON/.NET	HALCON/COM, HALCON/C++
C#	→	HALCON/.NET	HALCON/COM
Visual Basic (6.0)	→	HALCON/COM	
Visual Basic .NET	→	HALCON/.NET	HALCON/COM
Delphi	→	HALCON/COM	
Delphi .NET	→	HALCON/.NET	HALCON/COM

Table 1.1: Which interface to use for which programming language.

1.2 Platform-Specific HALCON Versions

You can use HALCON under Windows, Linux, and Mac OS X. The summary of system requirements is listed in table 1.2; more details follow below.

Operating System	Processor	Compiler / Environment
Windows	Intel Pentium 4 / AMD Athlon 64 or higher	Microsoft Visual Studio 6.0 or higher
Windows x64	Intel 64 or AMD64	Microsoft Visual Studio 6.0 or higher
Linux	Intel Pentium 4 / AMD Athlon 64 or higher	`gcc 4.x`
Linux x86_64	Intel 64 or AMD64	`gcc 4.x`
Mac OS X 10.7	Intel 64	Xcode 4

Table 1.2: Platforms supported by HALCON.

Additional Linux Requirements

The Linux distribution has to be LSB compliant. The corresponding packages have to be installed, e.g., redhat-lsb (Fedora, RedHat), lsb (SuSE), lsb-base + lsb-core (Ubuntu).

Furthermore, an XServer has to be installed. This is required even for command-line tools provided with HALCON.

Platform-Specific HALCON Versions

For each of the operating systems listed in table 1.2, platform-specific versions of HALCON's executables and libraries are provided. Table 1.3 lists all platform-specific versions with detailed system requirements. The name of the currently used version is stored in the environment variable `HALCONARCH`.

Note that HALCON should also run on newer versions of the operating systems than the ones listed; however, we cannot guarantee this.

`HALCONARCH` appears in several directory paths: Executable HALCON programs like `hdevelop`, and DLLs like `halcon.dll` (Windows only), reside in `%HALCONROOT%\bin\%HALCONARCH%`. On Windows systems, this path is therefore automatically included in the environment variable `PATH`; on a Linux system, you must include it in your login script.

The libraries that you need for linking programs, e.g., `halcon.lib` (Windows) or `libhalcon.so` (Linux) `%HALCONROOT%\lib\%HALCONARCH%`.

Please note that when creating a 64-bit application, both the development computer and the computer on which the application will run must be 64-bit platforms. On the other hand, you can use a 32-bit HALCON version on a 64-bit platform.

Further note that in order to create .NET applications under Linux/Mac OS X you need to install Mono.

HALCONARCH	Operating System, Processor	Compiler
x86sse2-win32	Windows XP/2003/Vista/2008/7, on x86 processor with SSE2 extension, e.g., Intel Pentium 4 / AMD Athlon 64 or higher	Visual Studio 6.0 or higher
x64-win64	Windows XP/2003/Vista/2008/7 x64 Edition, on Intel 64 or AMD64	Visual Studio 2005 or higher
x86sse2-linux2.4-gcc40	Linux, Kernel 2.4 or higher, libc.so.6 (GLIBC_2.3.4 or higher), libstdc++.so.6 (GLIBCXX_3.4 or higher), on x86 processor with SSE2 extension, e.g., Intel Pentium 4 / AMD Athlon 64 or higher	gcc 3.4/4.x
x64-linux2.4-gcc40	Linux x86_64, Kernel 2.4 or higher, libc.so.6 (GLIBC_2.3.4 or higher), libstdc++.so.6 (GLIBCXX_3.4 or higher), on Intel 64 or AMD64	gcc 3.4/4.x
x64-macosx	Mac OS X 10.7 on Intel 64	Xcode 4

Table 1.3: Values of HALCONARCH and detailed system requirements.

Platform-Independent Applications

Even when using a platform-specific version of HALCON, you can still create platform-independent applications, in two ways:

- **With HDevelop**, HALCON's integrated development environment (IDE). HDevelop programs are stored in a platform-independent format, thus, you can run them on any supported platform.
- **With HALCON/.NET**, HALCON's interface to .NET programming languages. Applications written in .NET languages are stored in a platform-independent intermediate language, which is then converted by the so-called common language runtime into platform-specific code.

You can combine both methods by using HDevEngine/.NET to run HDevelop programs from a HALCON/.NET application.

Chapter 2

Parallel Programming and HALCON

This chapter explains how to use HALCON on multi-core or multi-processor hardware, concentrating on the main features: automatic parallelization (section 2.1) and the support of parallel programming (section 2.2 on page 19).

2.1 Automatic Parallelization

If HALCON is used on multi-processor or multi-core hardware, it will automatically parallelize image processing operators. Section 2.1.1 describes how to initialize HALCON in order to use this mechanism. Section 2.1.2 explains the different methods which are used by HALCON operators for their automatic parallelization.

2.1.1 Initializing HALCON

In order to adapt the parallelization mechanism optimally to the actual hardware, HALCON needs to examine this hardware once. Afterwards, HALCON programs will be automatically parallelized without needing any further action on your part. Even existing HALCON programs will run and be parallelized without needing to be changed.

You trigger this initial examination by calling the operator `optimize_aop` (see the corresponding entry in the HALCON Reference Manuals for further information). Note, that this operator will only work correctly if called on a multi-core or multi-processor hardware; if you call the operator on a single-processor or single-core computer, it will return an error message. As a shortcut, you may call the executable `hcheck_parallel` which resides in the directory `%HALCONROOT%\bin\%HALCONARCH%`.

Upon calling `optimize_aop`, HALCON examines every operator that can be sped up in principle by an automatic parallelization. Each examined operator is processed several times - both sequentially and in parallel - with a changing set of input parameter values, e.g., images. The latter helps to evaluate

dependencies between an operator's input parameter characteristics (e.g. the size of an input image) and the efficiency of its parallel processing. Note that this examination may take some hours, depending on your computer and the optimization parameters!

The extracted information is stored in the file `.aop_info` in the common application data folder (under Windows) or in the HALCON installation directory `$HALCONROOT` (under Linux). Please note, that on some operating systems you need special privileges to initialize HALCON successfully, otherwise the operator `optimize_aop` is not able to store the extracted information. Note that in order to **execute command line tools with administrator privileges under Windows Vista and higher**, you will need to select "Run as Administrator" (even if you are already logged in as administrator).

Please refer to the examples in the directory `%HALCONEXAMPLES%\hdevelop\System\Parallelization` for more information about `optimize_aop` and about other operators that allow to query and modify the parallelization information.

2.1.2 The Methods of Automatic Parallelization

For the automatic parallelization of operators, HALCON exploits *data parallelism*, i.e., the property that parts of the input data of an operator can be processed independently of each other. Data parallelism can be found at four levels:

1. **tuple level**
   If an operator is called with iconic input parameters containing tuples, i.e., arrays of images, regions, or XLDs, it can be parallelized by distributing the tuple elements, i.e., the individual images, regions, or XLDs, on parallel threads. This method requires that *all input parameters* contain the *same number of tuple elements* (or contain a single iconic object or value).
2. **channel level**
   If an operator is called with input images containing multiple channels, it can be parallelized by distributing the channels on parallel threads. This method requires that *all input image objects* contain the *same number of channels* or a single channel image.
3. **domain level**
   An operator supporting this level can be parallelized by dividing its domain and distributing its parts on parallel threads.
4. **internal data level**
   Only parts of the operator are parallelized. The actual degree of parallelization depends on the implementation of the operator. As a result, the potential speedup on multi-core systems varies among operators utilizing this parallelization method.

The description of a HALCON operator in the Reference Manuals contains an entry called 'Parallelization Information', which specifies its behavior when using HALCON on a multi-core or multi-processor hardware. This entry indicates whether the operator will be automatically parallelized by HALCON and by which method (tuple, channel, domain, internal data).

The parallelization method of an arbitrary operator *opname* can also be determined using `get_operator_info`:

```
get_operator_info('opname', 'parallel_method', Information)
```

2.2 Parallel Programming Using HALCON

HALCON supports parallel programming by being *thread-safe* and *reentrant*, i.e., different threads can call HALCON operators simultaneously without having to wait. However, not all operators are fully reentrant. This section takes a closer look at the reentrancy of HALCON. Furthermore, it points out issues that should be kept in mind when writing parallel programs that use HALCON.

The example program `example_multithreaded1.c` in the directory `example\c` shows how to use multithreading to extract different types of components on a board in parallel using HALCON/C.

Furthermore, HALCON provides special operators to synchronize threads (see section 2.2.3 on page 21).

2.2.1 A Closer Look at Reentrancy

In fact there are different "levels" of reentrancy for HALCON operators:

1. **reentrant**
   An operator is fully reentrant if it can be called by multiple threads simultaneously independent of the data it is called with.

   Please note that you must take special care when multiple threads use the same data objects, e.g., the same image variable. In this case, you must synchronize the access to this variable manually using the corresponding parallel programming mechanisms (mutexes, semaphores). Better still is to avoid such cases as far as possible, i.e., to use local variables. Note that this is no special problem of HALCON but of parallel programming in general.

2. **local**
   This level of reentrancy is only relevant under Windows.

   Under Windows, operators marked as *local* should be called only from the thread that instantiates the corresponding objects. Typical examples are operators that use graphical I/O functions, which should only be used in the *main thread*. The reason is that under Windows, there exists a direct mapping between program threads and graphical elements, such as windows, dialog boxes or button controls. In short, a graphical element only exists in the context of its associated thread. This can cause severe problems (for example, hang the application) if a thread tries to perform user interactions via graphical elements that belong to another thread. For example, you may get a deadlock if one thread opens a window via `open_window` and another thread tries to get input from this window via `draw_circle`.

3. **single write multiple read**
   A certain group of operators should be called simultaneously only if the different calling threads work on different data. For example, threads should not try to modify the same template for pattern matching simultaneously by calling `adapt_template` with the same handle. Exactly the same applies to the case that one thread should not modify a data set that is simultaneously read by another thread. Other groups of operators with this behavior are concerned with file I/O (e.g., `write_image` – `read_image`, `fwrite_string` – `fread_string` but also non-HALCON file commands) or background estimation (e.g., `update_bg_esti` – `give_bg_esti`).

   As this thread behavior is not recommended quite generally, HALCON does not actively prevent it and thus saves overhead. This means that if you (accidentally) call such operators simultaneously with the same data no thread will block, but you might get unwelcome effects.

4. **mutual exclusive**
   Some operators cannot be called simultaneously by multiple threads but may be executed in parallel to *other* HALCON operators. Examples for mutual exclusive operators are `combine_roads_xld`, `pouring`, or `concat_ocr_trainf`.

5. **completely exclusive**
   A group of operators is executed exclusively by HALCON, i.e., while such an operator is executed, all other threads cannot call another HALCON operator. Examples are all OCR/OCV operators that modify OCR classifiers, all operators that create or delete files, and the operator `reset_obj_db`. The latter is switched off by default, together with the HALCON database of iconic objects. If, however, you switch the database on via `set_system`, you must assure that all operators that are to be executed *before* `reset_obj_db` is called have already finished, because this operator resets HALCON and therefore strongly influences its behavior.

6. **independent**
   A group of operators is executed independently from other, even exclusive operators. Examples are all tuple operators.

As mentioned already, the description of a HALCON operator in the Reference Manuals contains an entry called 'Parallelization Information', which specifies its behavior when using HALCON. This entry specifies the level of reentrancy as described above.

2.2.2 Style Guide

The following tips are useful for multithreaded programming in general:

- **Number of threads $\leq$ number of processors or cores**
  If you use more threads than there are processors or cores, your application might actually be slower than before because of the synchronization overhead. Note that when counting threads only the so-called *worker threads* are relevant, i.e., threads that are running / working continuously.

- **Local variables**
  If possible, use local variables, i.e., instantiate variables in the thread that uses them. If multiple threads use the same variable, you must synchronize their access to the variable using the appropriate parallel programming constructs (mutexes, semaphores; please refer to the documentation of your programming language for details).

  An exception are COM applications that use the so-called "Single-Threaded Apartment" mode, because here calls are synchronized automatically. This mode, however, has other disadvantages, as described in more detail in the tip for HALCON/COM below.

When using HALCON, please keep the following tips in mind:

- **Initialization**
  Before calling HALCON operators in parallel in a multithreaded program, you have to call one operator exclusively. This is necessary to allow HALCON to initialize its internal data structures.

- **I/O and visualization**
  Under Windows, use I/O operators (including graphics operators like `open_window` or `disp_image`) *locally, i.e., in the same thread*, otherwise you might get a deadlock. This means that you should not open a window in one thread and request a user interaction in it from another

thread. In the Reference Manual, these operators are marked as *locally reentrant* (see section 2.2.1 on page 19).

For HALCON/.NET, this typically means that all visualization must be performed in the main thread, because `HWindowControl` (see section 16.3 on page 128) is instantiated in the main thread. However, other threads can also "delegate" the display to the main thread as shown, e.g., in the example program `%HALCONEXAMPLES%\c#\MultiThreading` or `%HALCONEXAMPLES%\hdevengine\c#\MultiThreading` (the latter is described in detail in section 28.2.5.1 on page 241, the delegation of display on page 248).

Keep in mind that operators which create or delete files work exclusively, i.e., other threads have to wait.

The programmer has to assure that threads do not access the same file (or handle) simultaneously!

- **Multithreading vs. automatic parallelization**
  If you explicitly balance the load on multiple processors or cores in a multithreaded program, we recommend to switch off the automatic parallelization mechanism in order to get an optimal performance (or reduce the number of threads used by it so that the sum of threads does not exceed the number of processors or cores). How to switch of the automatic parallelization or reduce the number of threads is described in section 2.3.1.

- **HALCON/COM**
  Please note that in COM applications threads are created by default using the so-called "Single-Threaded Apartment" (STA) mode. In this mode, calls to COM objects (and thereby all calls of HALCON operators) are synchronized automatically with the windows message queue.

  Furthermore, in this apartment model calls to a COM object are always executed by the thread where the object was instantiated. Thus, if you instantiate `HFramegrabberX` in one thread and call `GrabImageAsync` in another, both threads are blocked during image acquisition! Therefore, it is very important to use local variables, i.e., instantiate objects in the thread that uses them (see above).

2.2.3 Multithreading Operators

In the operator section "System ▷ Multithreading", HALCON provides operators for creating and using synchronization objects like mutexes, events, condition variables, and barriers.

With them, you can synchronize threads in a platform-independent way. Note, however, that up to now no operators for creating the threads are provided.

2.2.4 Examples

HALCON currently provides the following examples for parallel programming (paths relative to `%HALCONEXAMPLES%`):

HALCON/C

- `c\source\example_multithreaded1.c`

  two threads extract different elements on a board in parallel

HALCON/.NET

- `c#\MultiThreading` (C#)

  performs image acquisition, processing, and display in three threads

- `hdevengine\c#\MultiThreading` (C#)

  executes the same HDevelop procedure in parallel by two threads using HDevEngine

- `hdevengine\c#\MultiThreadingTwoWindows` (C#)

  executes different HDevelop procedures in parallel by two threads using HDevEngine

HALCON/C++

- `mfc\FGMultiThreading` (using MFC)

  performs image acquisition / display and processing in two threads

- `mfc\MultiThreading` (using MFC)

  performs image acquisition, processing, and display in three threads

- `hdevengine\mfc\source\exec_programs_mt_mfc.cpp`

  executes HDevelop procedures for image acquisition, data code reading, and visualization in parallel using HDevEngine and MFC

- `hdevengine\cpp\source\exec_procedures_mt.cpp`

  executes HDevelop programs in parallel using HDevEngine

2.3 Additional Information

This section contains additional information that helps you to use HALCON on multi-core or multi-processor hardware.

2.3.1 Customizing the Parallelization Mechanisms

With the help of HALCON's system parameters, which can be set an queried with the operators `set_system` and `get_system`, respectively, you can customize the behavior of the parallelization mechanisms.

You can **query the number of processors (or cores)** by calling

```
get_system('processor_num', Information)
```

You can **switch off parts of the features of HALCON** with the help of the operator `set_system`. To switch off the automatic parallelization mechanism, call (HDevelop notation, see the Reference Manual for more information)

```
set_system('parallelize_operators','false')
```

To switch of reentrancy, call

```
set_system('reentrant','false')
```

Of course, you can switch on both behaviors again by calling set_system with 'true' as the second parameter. Please note that when switching off reentrancy you also switch off automatic parallelization, as it requires reentrancy.

Switch off these features only if you are sure you don't need them but want to save the corresponding computing overhead. e.g., if you write a sequential program that will never run on a multi-processor or multi-core computer.

A reason for switching off the automatic parallelization mechanism could be if your multithreaded program does its own scheduling and does not want HALCON to interfere via automatic parallelization. Note that you do not need to switch off automatic parallelization when using HALCON on a single-processor or single-core computer; HALCON does so automatically if it detects only one processor or core.

When switching off the automatic parallelization, you might consider switching off the use of thread pools (see the parameter 'thread_pool' of set_system).

Please **do not switch on reentrancy if this is already the case!** Otherwise, this will reset the parallelization system, which includes switching on the automatic operator parallelization. This will decrease the performance in case of manual parallelization (multithreading).

With the system parameter 'parallelize_operators' you can customize the automatic parallelization mechanisms in more detail. Please see the description of set_system for more information.

Finally, you can **influence the number of threads used for automatic parallelization** with the parameters 'thread_num' and 'tsp_thread_num' (set_system). Reducing the number of threads is useful if you also perform a manual parallelization in your program. If you switch off automatic parallelization permanently, you should also switch off the thread pool to save resources of the operating system.

2.3.2 Using an Image Acquisition Interface on Multi-Core or Multi-Processor Hardware

All image acquisition devices supported by HALCON can be used on multi-core or multi-processor hardware. Please note, that none of the corresponding operators is automatically parallelized. Most of the operators are reentrant, only the operators concerned with the connection to the device (open_framegrabber, info_framegrabber, close_framegrabber, and close_all_framegrabbers) are processed completely exclusively. Furthermore, these operators are *local*, i.e., under Windows they should be called from the thread that instantiates the corresponding object (see section 2.2.1 on page 19).

Chapter 3

Tips and Tricks

3.1 Monitoring HALCON Programs with HALCON Spy

HALCON Spy helps you to debug image processing programs realized with HALCON operators by monitoring calls to HALCON operators and displaying their input and output data in graphical or textual form. Furthermore, it allows you to step through HALCON programs. **Note that under Windows HALCON Spy does only work in combination with a console application**, i.e., you can not use it together with HDevelop.

HALCON Spy is activated within a HALCON program by inserting the line

```
set_spy('mode','on')
```

Alternatively, you can activate HALCON Spy for an already linked program by defining the environment variable `HALCONSPY` (i.e., by setting it to any value). How to set environment variables is described in the Installation Guide, section A.2 on page 64.

You specify the monitoring mode by calling the operator `set_spy` again with a pair of parameters, for example

```
set_spy('operator','on')
set_spy('input_control','on')
```

to be informed about all operator calls and the names and values of input control parameters. The monitoring mode can also be specified via the environment variable `HALCONSPY`, using a colon to separate multiple options:

```
operator=on:input_control=on
```

Please take a look at the entry for `set_spy` in the HALCON Reference Manuals for detailed information on all the debugging options.

3.1.1 HALCON Spy on Multi-Core or Multi-Processor Hardware

Please note that HALCON Spy cannot be used to debug multithreaded programs or programs using the automatic parallelization.

If you want to use HALCON Spy on a multi-core or multi-processor hardware, you must therefore first switch off the automatic parallelization as described in section 2.3.1 on page 22.

3.2 Terminate HALCON Library

In applications where DLLs are unloaded in a thread-exclusive context (such as applications using COM), the HALCON library will not terminate properly if the thread pool is still active, except when using the HALCON/COM interface.

A possible scenario where the problem may occur is, e.g., when using HALCON/C++ to implement an ATL control.

To overcome this problem, it is necessary to either call `set_system('thread_pool','false')` early enough before terminating the application (typically in the main application windows close event), or to disable thread pool cleanup by setting HShutdownThreadPool = FALSE at any time.

The latter setting implies a resource leak on termination. However, this is only relevant to applications that need to dynamically unload DLLs without terminating the application.

HALCON/COM will automatically set HShutdownThreadPool = FALSE. Other language interfaces, that are not normally used in a COM context, retain HShutdownThreadPool = TRUE so they may be unloaded without resource leak by default.

Part II

Programming With HALCON/C++

Chapter 4

Introducing HALCON/C++

HALCON/C++ is HALCON's interface to the programming language C++. Together with the HALCON library, it allows to use the image processing power of HALCON inside C++ programs.

Please note that the **HALCON/C++ interface described here was introduced in HALCON 11**. Older versions of HALCON used a different C++ interface which is still provided for backwards compatibility for some time and is referred to as HALCON/C++ (legacy) (see part III on page 67). Users are advised to use the new C++ interface. See chapter 9 on page 61 for information on how to compile legacy C++ applications, and how to convert legacy code to the new interface.

This part is organized as follows:

- In section 4.1, we start with a first example program.
- Chapter 5 on page 33 then takes a closer look at the basics of the HALCON/C++ interface,
- while chapter 6 on page 47 gives an overview of the classes `HImage`, etc.
- Chapter 7 on page 51 shows how to create applications based on HALCON/C++.
- Chapter 8 on page 57 presents typical image processing problems and shows how to solve them using HALCON/C++.
- Chapter 9 on page 61 compares HALCON/C++ to HALCON/C++ (legacy) and shows how to compile legacy C++ code or convert it to the new C++ interface.

4.1 A First Example

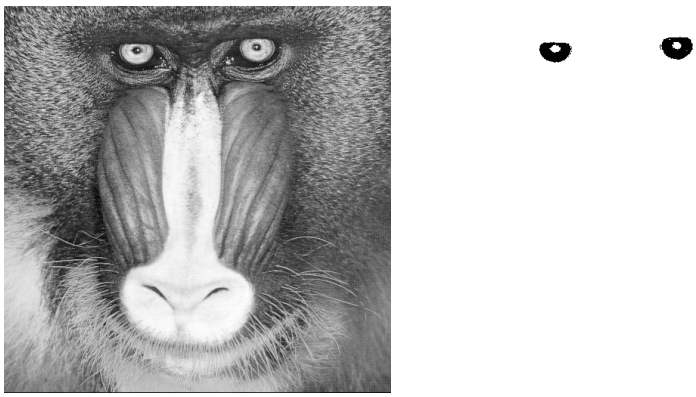


Figure 4.1: The left side shows the input image (a mandrill), and the right side shows the result of the image processing: the eyes of the monkey.

The input image is shown in figure 4.1 on the left side. The task is to find the eyes of the monkey by segmentation. The segmentation of the eyes is performed by the C++ program listed in figure 4.2, the result of the segmentation process is shown in figure 4.1 on the right side.

The program is more or less self-explaining. The basic idea is as follows: First, all pixels of the input image are selected which have a gray value of at least 128, on the assumption that the image `Mandrill` is a byte image with a gray value range between 0 and 255. Secondly, the connected component analysis is performed. The result of the HALCON operator is an array of regions. Each region is isolated in the sense that it does not touch another region according to the neighbourhood relationship. Among these regions those two are selected which correspond to the eyes of the monkey. This is done by using shape properties of the regions, the size and the anisometry.

This example shows how easy it is to integrate HALCON operators in any C++ program. Their use is very intuitive: You don't have to care about the underlying data structures and algorithms, you can ignore specific hardware requirements, if you consider e.g. input and output operators. HALCON handles the memory management efficiently and hides details from you, and provides an easy to use runtime system.

```
#include "HalconCpp.h"

int main()
{
  using namespace HalconCpp;

  HImage Mandrill("monkey");                // read image from file "monkey"
  Hlong width,height;
  Mandrill.GetImageSize(&width,&height);

  HWindow w(0,0,width,height);              // window with size equal to image

  Mandrill.DispImage(w);                    // display image in window
  w.Click();                                // wait for mouse click
  w.ClearWindow();

  HRegion Bright = Mandrill >= 128;         // select all bright pixels
  HRegion Conn = Bright.Connection();       // get connected components

  // select regions with a size of at least 500 pixels
  HRegion Large = Conn.SelectShape("area","and",500,90000);

  // select the eyes out of the instance variable Large by using
  // the anisometry as region feature:
  HRegion Eyes = Large.SelectShape("anisometry","and",1,1.7);

  Eyes.DispRegion(w);                       // display result image in window
  w.Click();                                // wait for mouse click
}
```

Figure 4.2: This program extract the eyes of the monkey.

Chapter 5

Basics of the HALCON/C++ Interface

The HALCON/C++ interface provides two different approaches to use HALCON's functionality within your C++ program: a *procedural* and an *object-oriented* approach. The procedural approach corresponds to calling HALCON operators directly as in C or HDevelop, e.g.:

```
HObject original_image, smoothed_image;
ReadImage(&original_image, "monkey");
MeanImage(original_image, &smoothed_image, 11, 11);
```

In addition to the procedural approach, HALCON/C++ allows to call HALCON operators in an object-oriented way, i.e., via a set of classes. For example, the code from above can be "translated" into:

```
HImage original_image("monkey");
HImage smoothed_image = original_image.MeanImage(11, 11);
```

This simple example already shows that the two approaches result in clearly different code: The operator calls differ in the number and type of parameters. Furthermore, functionality may be available in different ways; for example, images can be read from files via a constructor of the class `HImage`. In general, we recommend to use the object-oriented approach. Note, however, that HDevelop can export programs only as procedural C++ code. Section 5.5 on page 43 shows how to combine procedural with object-oriented code.

In the following sections, we take a closer look at various issues regarding the use of the HALCON/C++ interface; chapter 6 on page 47 describes the provided classes in more detail.

5.1 The Namespace HalconCpp

Starting with HALCON 11, all functions and classes of HALCON/C++ use the namespace `HalconCpp` to prevent potential name conflicts with other C++ libraries.

You can specify ("use") the namespace in three ways:

- **specifically**, by prefixing each class name or operator call with the namespace

```
HalconCpp::HObject  original_image, smoothed_image;
HalconCpp::ReadImage(&original_image, "monkey");
```

- **locally**, by placing the directive `using namespace HalconCpp;` at the beginning of a block, e.g., at the beginning of a function:

```
int main(int argc, char *argv[])
{
  using namespace HalconCpp;

  HObject original_image, smoothed_image;
  ReadImage(&original_image, "monkey");
```

  Then, you can use HALCON's classes and functions without prefix inside this block.

- **globally**, by placing the directive `using` directly after including `HalconCpp.h`. Then, you do not need the prefix in your whole application.

```
#include "HalconCpp.h"
using namespace HalconCpp;
```

Which method is the most suitable depends on your application, more exactly on what other libraries it includes and if there are name collisions.

Please note that the namespace is not mentioned in the operator descriptions in the reference manual in order to keep it readable. Similarly, in the following sections the namespace is left out.

5.2 Calling HALCON Operators

How a HALCON operator can be called via the HALCON/C++ interface is described in detail in the HALCON operator reference manual. As an example, figure 5.1 shows parts of the entry for the operator `MeanImage`.

Please note that the reference manual does not list all possible signatures of the operators. A complete list can be found in the file `include\cpp\HCPPGlobal.h`.

Below, we

- take a closer look at the parameters of an operator call (section 5.2.1)
- describe how to call operators via classes (section 5.2.2 on page 37) or via special constructors (section 5.2.3 on page 38) or destructors (section 5.2.4 on page 39)
- explain another special HALCON concept, the *tuple mode* (section 5.2.5 on page 39)

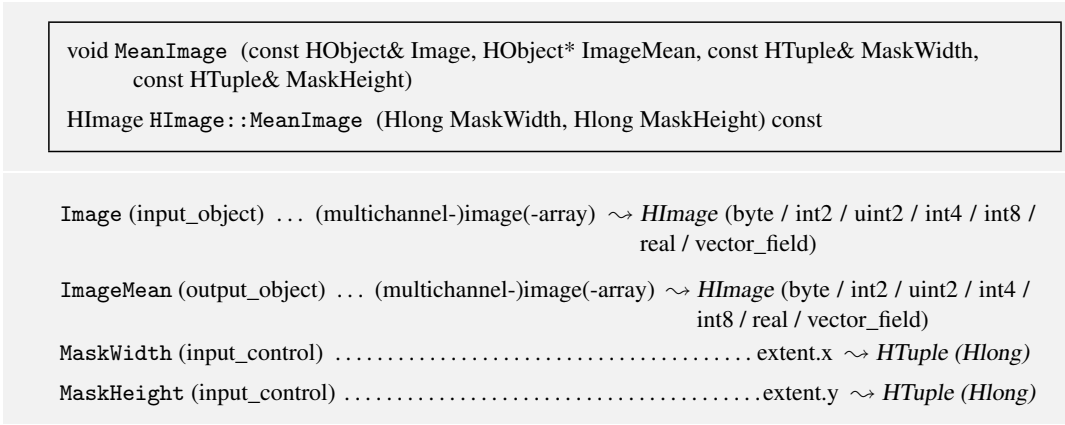

void MeanImage (const HObject& Image, HObject* ImageMean, const HTuple& MaskWidth, const HTuple& MaskHeight)
HImage HImage::MeanImage (Hlong MaskWidth, Hlong MaskHeight) const
Image (input_object) ... (multichannel-)image(-array) ⇝ HImage (byte / int2 / uint2 / int4 / int8 / real / vector_field)
ImageMean (output_object) ... (multichannel-)image(-array) ⇝ HImage (byte / int2 / uint2 / int4 / int8 / real / vector_field)
MaskWidth (input_control) ..... extent.x ⇝ HTuple (Hlong)
MaskHeight (input_control) ..... extent.y ⇝ HTuple (Hlong)

Figure 5.1: The head and parts of the parameter section of the reference manual entry for `mean_image`.

5.2.1 A Closer Look at Parameters

HALCON distinguishes two types of parameters: *iconic* and *control* parameters. *Iconic parameters* are related to the original image (images, regions, XLD objects), whereas *control parameters* are all kinds of alphanumerical values, such as integers, floating-point numbers, or strings.

A special form of control parameters are the so-called *handles*. A well-known representative of this type is the *window handle*, which provides access to an opened HALCON window, e.g., to display an image in it. Besides, handles are used when operators share complex data, e.g., the operators for shape-based matching which create and then use the model data, or for accessing input/output devices, e.g., image acquisition devices. Classes encapsulating handles are described in detail in section 6.2.2 on page 49.

Both iconic and control parameters can appear as input and output parameters of a HALCON operator. For example, the operator `MeanImage` expects one iconic input parameter, one iconic output parameter, and two input control parameters (see figure 5.1); figure 5.2 shows an operator which has all four parameter types. Note how some parameters "disappear" from within the parentheses if you call an operator via a class; this mechanism is described in more detail in section 5.2.2 on page 37.

An important concept of HALCON's philosophy regarding parameters is that **input parameters are not modified by an operator**. As a consequence, they are passed *by value* (e.g., `Hlong MaskWidth` in figure 5.1) or via a constant reference (e.g., `const HObject& Image`). This philosophy also holds if an operator is called via a class, with the calling instance acting as an input parameter. Thus, in the following example code the original image is not modified by the call to `MeanImage`; the operator's result, i.e., the smoothed image, is provided via the return value instead:

```
HImage original_image("monkey");
HImage smoothed_image = original_image.MeanImage(11, 11);
```

In contrast to input parameters, output parameters are always modified, thus they must be passed *by reference*. Note that operators expect a pointer to **an already existing variable or class instance**! For example, when calling the operator `FindBarCode` as in the following lines of code, variables of the class `HTuple` are declared before passing the corresponding pointers using the operator `&`.

void FindBarCode (const HObject& Image, HObject* SymbolRegions,
const HTuple& BarCodeHandle, const HTuple& CodeType, HTuple* DecodedDataStrings)

HRegion HBarCode::FindBarCode (const HImage& Image, const HTuple& CodeType,
HTuple* DecodedDataStrings) const

HRegion HBarCode::FindBarCode (const HImage& Image, const HString& CodeType,
HString* DecodedDataStrings) const

HRegion HBarCode::FindBarCode (const HImage& Image, const char* CodeType,
HString* DecodedDataStrings) const

HRegion HImage::FindBarCode (const HBarCode& BarCodeHandle, const HTuple& CodeType,
HTuple* DecodedDataStrings) const

HRegion HImage::FindBarCode (const HBarCode& BarCodeHandle, const HString& CodeType,
HString* DecodedDataStrings) const

HRegion HImage::FindBarCode (const HBarCode& BarCodeHandle, const char* CodeType,
HString* DecodedDataStrings) const

Image (input_object) ..... singlechannelimage ⇝ *HImage* (byte / uint2)

SymbolRegions (output_object) ..... region(-array) ⇝ *HRegion*

BarCodeHandle (input_control) ..... barcode ⇝ *HTuple (Hlong)*

CodeType (input_control) ..... string(-array) ⇝ *HTuple (HString)*

DecodedDataStrings (output_control) ..... string(-array) ⇝ *HTuple (HString)*

Figure 5.2: The head and parts of the parameter section of the reference manual entry for `find_bar_code`.

```
HImage          image("barcode/ean13/ean1301");
HBarCode        barcode(HTuple(), HTuple());
HString         result;

HRegion code_region = barcode.FindBarCode(image, "EAN-13", &result);
```

The above example shows another interesting aspect of output parameters: When calling operators via classes, one output parameter may become the return value (see section 5.2.2 for more details); in the example, `FindBarCode` returns the bar code region.

Many HALCON operators accept more than one value for certain parameters. For example, you can call the operator `MeanImage` with an array of images (see figure 5.1); then, an array of smoothed images is returned. This is called the *tuple mode*; see section 5.2.5 on page 39 for more information.

String Parameters

Output strings are always of type `HString` with automatic memory management. In the following example code, the operator `InfoFramegrabber` (see also figure 5.3) is called with two output string parameters to query the currently installed image acquisition board:

void InfoFramegrabber (const HTuple& Name, const HTuple& Query, HTuple* Information, HTuple* ValueList)

HString HInfo::InfoFramegrabber (const HString& Name, const HString& Query, HTuple* ValueList)

HString HInfo::InfoFramegrabber (const char* Name, const char* Query, HTuple* ValueList)

Name (input_control) ..... string ⇝ *HTuple (HString)*

Query (input_control) ..... string ⇝ *HTuple (HString)*

Information (output_control) ..... string ⇝ *HTuple (HString)*

ValueList (output_control) ..... string-array ⇝ *HTuple (HString* / Hlong / double)

Figure 5.3: The head and parts of the parameter section of the reference manual entry for info_framegrabber.

```
HString     sInfo, sValue;

InfoFramegrabber(FGName, "info_boards", &sInfo, &sValue);
```

Note that it is also not necessary to allocate memory for multiple output string parameters returned as HTuple:

```
HTuple      tInfo, tValues;

InfoFramegrabber(FGName, "info_boards", &tInfo, &tValues);
```

5.2.2 Calling Operators via Classes

As already described in the previous section, the HALCON/C++ reference manual shows via which classes an operator can be called. For example, FindBarCode can be called via objects of the class HImage or HBarCode (see figure 5.2 on page 36). In both cases, the corresponding input parameter (Image or BarCodeHandle, respectively) does not appear within the parentheses anymore as it is replaced by the calling instance of the class (this).

There is a further difference to the procedural operator signature: The first output parameter (in the example the bar code region SymbolRegions) also disappears from within the parentheses and becomes the return value instead of the error code (more about error handling can be found in section 5.3 on page 43).

Figure 5.4 depicts code examples for the three ways to call FindBarCode. When comparing the object-oriented and the procedural approach, you can see that the calls to the operators ReadImage and CreateBarCodeModel are replaced by special constructors for the classes HImage and HBarCode, respectively. This topic is discussed in more detail below.

```
HImage          image("barcode/ean13/ean1301");
HBarCode        barcode(HTuple(), HTuple());
HString         result;


HRegion code_region = barcode.FindBarCode(image, "EAN-13", &result);
```

```
HRegion code_region = image.FindBarCode(barcode, "EAN-13", &result);
```

```
HObject         image;
HTuple          barcode;
HObject         code_region;
HTuple          result;

ReadImage(&image, "barcode/ean13/ean1301");
CreateBarCodeModel(HTuple(), HTuple(), &barcode);
FindBarCode(image, &code_region, barcode, "EAN-13", &result);
```

Figure 5.4: Using `FindBarCode` via `HBarCode`, via `HImage`, or in the procedural approach.

5.2.3 Constructors and Halcon Operators

As can be seen in figure 5.4, the HALCON/C++ parameter classes provide additional constructors, which are based on suitable HALCON operators. The constructors for `HImage` and `HBarCode` used in the example are based on `ReadImage` and `CreateBarCodeModel`, respectively.

As a rule of thumb: If a class appears only as an output parameter in an operator, there automatically exists a constructor based on this operator. Thus, instances of `HBarCode` can be constructed based on `CreateBarCodeModel` as shown in figure 5.4, instances of `HShapeModel` based on `CreateShapeModel`, instances of `HFramegrabber` based on `OpenFramegrabber` and so on. Note that for classes where many such operators exist (e.g., `HImage`), only a subset of commonly used operators with unambiguous parameter list are actually used as constructor.

In addition, all classes have empty constructors to create an uninitialized object. For example, you can create an instance of `HBarCode` with the default constructor and then initialize it using `CreateBarCodeModel` as follows:

```
HBarCode        barcode;
barcode.CreateBarCodeModel(HTuple(), HTuple());
```

If the instance was already initialized, the corresponding data structures are automatically destroyed before constructing and initializing them anew (see also section 5.2.4). The handle classes are described in more detail in section 6.2.2.2 on page 50.

```
HImage image;                   // still uninitialized
image.ReadImage("clip");
```

Below we take a brief look at the most important classes. A complete and up-to-date list of available constructors can be found in the HALCON operator reference and the corresponding header files in `%HALCONROOT%\include\cpp`.

- **Images:**
  The class `HImage` provides constructors based on the operators `ReadImage`, `GenImage1`, and `GenImageConst`.
- **Regions:**
  The class `HRegion` provides constructors based on operators like `GenRectangle2` or `GenCircle`.
- **Windows:**
  The class `HWindow` provides a constructor based on the operator `OpenWindow`.

  Of course, you can close a window using `CloseWindow` and then open it again using `OpenWindow`. In contrast to the iconic parameter classes, you can call the "constructor-like" operator `OpenWindow` via an instance of `HWindow` in the intuitive way, i.e., the calling instance is modified; in addition the corresponding handle is returned. `HWindow` is described in more detail in section 6.2.2.1 on page 50.

5.2.4 Destructors and Halcon Operators

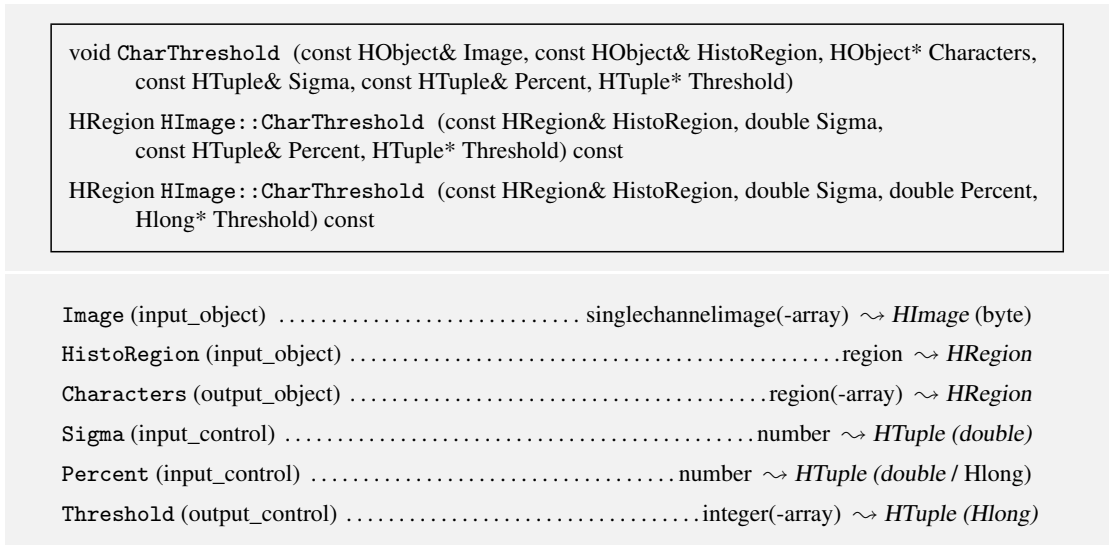
All HALCON/C++ classes provide default destructors which automatically free the corresponding memory. For some classes, the destructors are based on suitable operators:

- **Windows:**
  The default destructor of the class `HWindow` closes the window based on `CloseWindow`. Note that the operator itself is no destructor, i.e., you can close a window with `CloseWindow` and then open it again using `OpenWindow`.
- **Other Handle Classes:**
  The default destructors of the other classes encapsulating handles, e.g., `HShapeModel` or `HFramegrabber`, apply operators like `ClearShapeModel` or `CloseFramegrabber`, respectively. In contrast to `CloseWindow`, these operators cannot be called via instances of the class, as can be seen in the corresponding reference manual entries; the same holds for operators like `ClearAllShapeModels`. In fact, there is no need to call these operators as you can initialize instances anew as described in section 5.2.3.

  Please note that you must not use operators like `ClearShapeModel`, `ClearAllShapeModels`, or `CloseFramegrabber` together with instances of the corresponding handle classes!

5.2.5 The Tuple Mode

As already mentioned in section 5.2.1 on page 35, many HALCON operators can be called in the so-called *tuple mode*. In this mode, you can, e.g., apply an operator to multiple images or regions with a single call. The standard case, e.g., calling the operator with a single image, is called the *simple mode*. Whether or not an operator supports the tuple mode can be checked in the reference manual. For example, take a look at figure 5.5, which shows an extract of the reference manual entry for the operator



void CharThreshold (const HObject& Image, const HObject& HistoRegion, HObject* Characters, const HTuple& Sigma, const HTuple& Percent, HTuple* Threshold)

HRegion HImage::CharThreshold (const HRegion& HistoRegion, double Sigma, const HTuple& Percent, HTuple* Threshold) const

HRegion HImage::CharThreshold (const HRegion& HistoRegion, double Sigma, double Percent, Hlong* Threshold) const

Image (input_object) ..... singlechannelimage(-array) ⇝ *HImage* (byte)

HistoRegion (input_object) ..... region ⇝ *HRegion*

Characters (output_object) ..... region(-array) ⇝ *HRegion*

Sigma (input_control) ..... number ⇝ *HTuple (double)*

Percent (input_control) ..... number ⇝ *HTuple (double* / Hlong)

Threshold (output_control) ..... integer(-array) ⇝ *HTuple (Hlong)*

Figure 5.5: The head and parts of the parameter section of the reference manual entry for CharThreshold.

CharThreshold: In the parameter section, the parameter Image is described as an image(-array); this signals that you can apply the operator to multiple images at once.

If you call CharThreshold with multiple images, i.e., with an image tuple, the output parameters automatically become tuples as well. Consequently, the parameters Characters and Threshold are described as region(-array) and integer(-array), respectively.

Note that the class HTuple can also contain arrays (tuples) of control parameters of mixed type; please refer to section 6.2.1 on page 49 for more information about this class. In contrast to the control parameters, the iconic parameters remain instances of the class HObject in both modes, as this class can contain both single objects and object arrays.

In the object-oriented approach, control parameters can be of a basic type (simple mode only) or instances of HTuple (simple and tuple mode).

After this rather theoretic introduction, let us take a look at example code. In figure 5.6, CharThreshold is applied in simple mode, i.e., to a single image, in figure 5.7 to two images at once. Both examples are realized both in the object-oriented and in the procedural approach. The examples highlight some interesting points:

- **Access to iconic objects:**
  As expected, in the object-oriented approach, the individual images and regions are accessed via the array operator []; the number of objects in an array can be queried via the method CountObj(). In the procedural approach, objects must be selected explicitly using the operator SelectObj; the number of objects can be queried via CountObj.

  Note that object indexes start with 1 (as used by SelectObj.

- **Polymorphism of HObject:**
  The class HObject is used for all types of iconic objects. What is more, image objects can be used

```
HImage          image("alpha1");
HRegion         region;
Hlong           threshold;

region = image.CharThreshold(image.GetDomain(), 2, 95, &threshold);
image.DispImage(window);
region.DispRegion(window);
cout << "Threshold for 'alpha1': " << threshold;
```

```
HObject         image;
HObject         region;
HTuple          threshold;

ReadImage(&image, "alpha1");
CharThreshold(image, image, &region, 2, 95, &threshold);
DispObj(image, window);
DispObj(region, window);
cout << "Threshold for 'alpha1': " << threshold;
```

Figure 5.6: Using `CharThreshold` in simple mode, via `HImage`, or in the procedural approach (declaration and opening of window omitted).

for parameters expecting a region, as in the call to `CharThreshold` in the examples; in this case, the *domain* of the image, i.e., the region in which the pixels are "valid", is extracted automatically. The object-oriented approach supports an implicit cast from `HImage` to `HRegion`.

```
HImage         images;
HRegion        regions;
HTuple         thresholds;

images.GenEmptyObj();
for (int i=1; i<=2; i++)
{
  images = images.ConcatObj(HImage(HTuple("alpha") + i));
}

regions = images.CharThreshold(images.GetDomain()[1], 2, 95, &thresholds);

for (int i=1; i<=images.CountObj(); i++)
{
  images[i].DispImage(window);
  regions[i].DispRegion(window);
  cout << "Threshold for 'alpha" << i << "': " << thresholds[i-1].L();
  window.Click();
```

```
HObject        images, image;
HObject        regions, region;
HTuple         num;
HTuple         thresholds;

GenEmptyObj(&images);

for (int i=1; i<=2; i++)
{
  ReadImage(&image, HTuple("alpha") + i);
  ConcatObj(images, image, &images);
}

CharThreshold(images, image, &regions, 2, 95, &thresholds);
CountObj(images, &num);

for (int i=0; i<num; i++)
{
  SelectObj(images, &image, i+1);
  DispObj(image, window);
  SelectObj(regions, &region, i+1);
  DispObj(region, window);
  cout << "Threshold for 'alpha" << i+1 << "': " << thresholds[i].L();
}
```

Figure 5.7: Using `CharThreshold` in tuple mode, or in the procedural approach (declaration and opening of window omitted).

5.3 Error Handling

Error handling is fully based on exceptions using `try` ... `catch` blocks.

```
try
{
  image.ReadImage(filename);
}
catch (HException &except)
{
  if (except.ErrorNumber() == H_ERR_FNF)
  {
    // Handle file not found error
  }
  else
  {
    // Pass on unexpected error to caller
    throw except;
  }
}
```


5.4 Memory Management

All of HALCON's classes, i.e., not only `HImage`, `HRegion`, `HTuple`, `HFramegrabber` etc., but also the class `HObject` used when calling operators in the procedural approach, release their allocated resources automatically in their destructor (see also section 5.2.4 on page 39). Furthermore, when constructing instances anew, e.g., by calling `CreateBarCodeModel` via an already initialized instance as mentioned in section 5.2.3 on page 38, the already allocated memory is automatically released before reusing the instance. Thus, there is no need to call the operator `ClearObj` in HALCON/C++; what is more, if you do use it HALCON will complain about already released memory. To explicitly release the resources before the instance gets out of scope, you can call the method `Clear()` of the instance.

However, there is one occasion for explicit memory management on your part: This applies when using handles in the procedural approach: The memory allocated when creating a handle, e.g., with `OpenFramegrabber`, is only released when calling the "complementary" operator, in the example `CloseFramegrabber` — or at the end of the program.

5.5 How to Combine Procedural and Object-Oriented Code

As already noted, we recommend to use the object-oriented approach wherever possible. However, there are some reasons for using the procedural approach, e.g., if you want to quickly integrate code that is exported by HDevelop, which can only create procedural code.

The least trouble is caused by the basic control parameters as both approaches use the elementary types `long` etc. and the class `HTuple`. Iconic parameters and handles can be converted as follows:

- **Converting `HObject` into iconic parameter classes**

```
HObject        p_image;
ReadImage(&p_image, "barcode/ean13/ean1301");

HImage         o_image(p_image);
```

  Iconic parameters can be converted from `HObject` to, e.g., `HImage` simply by calling the constructor with the procedural variable as a parameter.

- **Converting handles into handle classes**

```
HTuple         p_barcode;
CreateBarCodeModel(HTuple(), HTuple(), &p_barcode);
HBarCode       o_barcode(p_barcode[0]);
o_code_region = o_barcode.FindBarCode(o_image, "EAN-13", &result);
```

  Handles cannot be converted directly via a constructor; instead, you call the method `SetHandle()` with the procedural handle as a parameter.

- **Accessing handle classes through handles**

```
p_barcode = o_barcode.GetHandle();
```

  Note that `o_barcode` remains the owner of the handle. To reset `o_barcode` without destroying the object, use `InvalidateHandle()`.

  Similarly, a handle can be extracted from the corresponding class via the method `GetHandle()`. You can even omit the method, as the handle classes provide cast operators which convert them automatically into handles.

```
p_barcode = o_barcode;
```

Note that instances of `HImage` can be used in procedural code where `HObject` is expected.

As already remarked in section 5.2.4 on page 39, you must not use operators like `ClearShapeModel`, `ClearAllShapeModels`, or `CloseFramegrabber` together with instances of the corresponding handle classes!

5.6 I/O Streams

HALCON/C++ provides iostream operators by default. Note that it may be necessary to enable the namespace `std`:

```
using namespace std;
```

If you want to use the older iostream interface (i.e., `<iostream.h>` instead of `<iostream>`), the following line has to be added (otherwise, there may be conflicts with the HALCON include files):

```
#define HCPP_NO_USE_IOSTREAM
```

Chapter 6

The HALCON Parameter Classes

The HALCON operator reference contains a complete list of the generic classes and member functions of HALCON/C++. This chapter contains a summary of additional convenience members.

In addition, HALCON/C++ contains many **operator overloads**, which are consistent with HALCON/.NET. See section 16.4.4 on page 133 for a list of the overloaded operators.

6.1 Iconic Objects

The base class of the iconic parameter classes in HALCON/C++ is the class `HObject` which manages entries in the database, i.e., the copying or releasing of objects. The class `HObject` can contain all types of iconic objects. This has the advantage that important methods like `DispObj()` can be applied to all iconic objects in the same manner.

Three classes are derived from the root class `HObject`:

- Class `HRegion` for handling regions.
- Class `HImage` for handling images.
- Class `HXLD` for handling polygons.

These classes are described in more detail below.

6.1.1 Regions

A region is a set of coordinates in the image plane. Such a region does not need to be connected and it may contain holes. A region can be larger than the actual image format. Regions are represented by the so-called runlength coding in HALCON. The class `HRegion` represents a region in HALCON/C++. Besides those operators that can be called via `HRegion` (see also section 5.2.2 on page 37), `HRegion` provides the following member functions:

- `HTuple HRegion::Area()`
  Area of the region, i.e., number of pixels, see reference manual entry of `AreaCenter`.
- `HTuple HRegion::Row()`
  Center row of the region.
- `HTuple HRegion::Column()`
  Center column of the region.

6.1.2 Images

There is more to HALCON images than just a matrix of pixels: In HALCON, this matrix is called a *channel*, and images may consist of one or more such channels. For example, gray value images consist of a single channel, color images of three channels. Channels can not only contain the standard 8 bit pixels (pixel type `byte`) used to represent gray value images, HALCON allows images to contain various other data, e.g. 16 bit integers (type `int2`) or 32 bit floating point numbers (type `real`) to represent derivatives. Besides the pixel information, each HALCON image also stores its so-called *domain* in form of a HALCON region. The domain can be interpreted as a region of interest, i.e., HALCON operators (with some exceptions) restrict their processing to this region.

- `HTuple HImage::Width()`
  Return the width of the image, see reference manual entry of `GetImageSize`.
- `HTuple HImage::Height()`
  Return the height of the image, see reference manual entry of `GetImageSize`.

6.1.3 XLD Objects

XLD is the abbreviation for e**X**tended **L**ine **D**escription. This is a data structure used for describing areas (e.g., arbitrarily sized regions or polygons) or any closed or open contour, i.e., also lines. In contrast to regions, which represent all areas at pixel precision, XLD objects provide subpixel precision. There are two basic XLD structures: contours and polygons.

HALCON/C++ provides both a base class `HXLD` and a set of specialized classes derived from `HXLD`, e.g., `HXLDCont` for contours or `HXLDPoly` for polygons.

In contrast to the classes described in the previous sections, the XLD classes provide only member functions corresponding to HALCON operators (see also section 5.2.2 on page 37).

6.2 Control Parameters

HALCON/C++ can handle different types of alphanumerical control parameters for HALCON operators:

- integer numbers (`Hlong`),
- floating point numbers (`double`), and

- strings (HString).

A special form of control parameters are the so-called *handles*, which provide access to more complex data structures like windows, image acquisition connections, or models for shape-based matching. Internally, handles are almost always represented by discrete numbers (long). For handles there exist corresponding classes, which are described in section 6.2.2.

With the class HTuple, HALCON/C++ provides a container class for control parameters. What's more, HTuple is polymorphic, i.e., it can also contain arrays of control parameters of mixed type.

6.2.1 Tuples

The class HTuple implements an array of dynamic length. The default constructor constructs an empty array (Length() == 0). This array can dynamically be expanded via assignments. The memory management, i.e., reallocation, freeing, is also managed by the class. The index for accessing the array is in the range between 0 and Length() − 1.

The following member functions reflect only a small portion of the total. For further information please refer to the file HTuple.h in %HALCONROOT%\include\cpp.

- HTuple &HTuple::Append(const HTuple& tuple)
  Append data to existing tuple.
- void HTuple::Clear()
  Clear all data inside the tuple.
- HTuple HTuple::Clone()
  Create a detached copy duplication the tuple data.
- Hlong HTuple::Length()
  Return the number of elements of the tuple.
- HTupleType HTuple::Type()
  Return the data type of the tuple (pure data types or mixed tuple).
- HString HTuple::ToString()
  Return a simple string representation of the tuple contents.
- Hlong* HTuple::LArr()
  double* HTuple::DArr()
  char** HTuple::SArr()
  Hcpar* HTuple::PArr()
  Access tuple data.

6.2.2 Classes Encapsulating Handles

The perhaps most prominent handle class is HWindow, which is described in section 6.2.2.1. HALCON/C++ also provides classes for handles to files or functionality like access to image acquisition devices, measuring, or shape-based matching. See section 6.2.2.2 for an overview.

6.2.2.1 Windows

The class `HWindow` provides the management of HALCON windows in a very convenient way. The properties of HALCON windows can be easily changed, images, regions, and polygons can be displayed, etc. Besides those operators that can be called via `HWindow` (see also section 5.2.2 on page 37), `HWindow` provides the following member functions:

- `void HWindow::Click()`
  Wait for a mouse click in the window.
- `void HWindow::CloseWindow()`
  Close the window.

6.2.2.2 Other Handle Classes

HALCON/C++ provides the so-called handle classes like `HFramegrabber`, `HBarCode`, or `HClassBoxMlp`.

Besides the default constructor, the classes typically provide additional constructors based on suitable operators as described in section 5.2.3 on page 38; e.g., the class `HBarCode` provides a constructor based on the operator `CreateBarCodeModel`.

All handle classes listed above provide the methods `SetHandle()` and `GetHandle()`, which allow to access the underlying handle; furthermore, the classes provide an operator that casts an instance of the class into the corresponding handle. These methods are typically used when combining procedural and object-oriented code; for examples please refer to section 5.5 on page 43.

The reference manual provides short overview pages for these classes, listing the operators that can be called via them.

Chapter 7

Creating Applications With HALCON/C++

The HALCON distribution contains examples for creating an application with HALCON/C++. The following sections show

- the relevant directories and files (section 7.1)
- the list of provided example applications (section 7.2 on page 53)
- the relevant environment variables (section 7.3 on page 53)
- how to create an executable under Windows (section 7.4 on page 54)
- how to create an executable under Linux (section 7.5 on page 54)
- how to create an executable under Mac OS X (section 7.6 on page 55)

7.1 Relevant Directories and Files

Here is an overview of the relevant directories and files (relative to `%HALCONROOT%`, Windows notation of paths):

`include\halconcpp\HalconCpp.h`:
include file; contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ interface.

`bin\%HALCONARCH%\halcon.dll`,
`lib\%HALCONARCH%\halcon.lib`:
The HALCON library (Windows).

`bin\%HALCONARCH%\halconcpp.dll`,

`lib\%HALCONARCH%\halconcpp.lib:`
The HALCON/C++ library (Windows).

`bin\%HALCONARCH%\halconxl.dll, halconcppxl.dll,`
`lib\%HALCONARCH%\halconxl.lib, halconcppxl.lib:`
The corresponding libraries of HALCON XL (Windows).

`lib/$HALCONARCH/libhalcon.so:`
The HALCON library (Linux).

`lib/$HALCONARCH/libhalconcpp.so:`
The HALCON/C++ library (Linux).

`lib/$HALCONARCH/libhalconxl.so,libhalconcppxl.so:`
The corresponding libraries of HALCON XL (Linux).

`/Library/Frameworks/HALCONCpp.framework`
The HALCON/C++ framework (Mac OS X).

`/Library/Frameworks/HALCONCppxl.framework`
The corresponding framework of HALCON XL (Mac OS X).

`include\HProto.h:`
External function declarations.

`%HALCONEXAMPLES%\cpp\console\makefiles\makefile, makefile.win:`
Example makefiles which can be used to compile the example programs (Linux/Mac OS X and Windows, respectively).

`%HALCONEXAMPLES%\cpp\make.%HALCONARCH%, macros.mak, rules.mak:`
Auxiliary makefiles included by the makefiles listed above.

`%HALCONEXAMPLES%\cpp\console\source\`
Directory containing the source files of the example programs.

`%HALCONEXAMPLES%\cpp\console\vs2005\examples.sln:`
Visual Studio 2005 solution containing projects for all examples; the projects themselves are placed in subdirectories (Windows only).

`%HALCONEXAMPLES%\cpp\console\bin\%HALCONARCH%\`
Destination of the example programs when compiled and linked using the makefiles.

`%HALCONEXAMPLES%\images\:`
Images used by the example programs.

`help\operators_*:`
Files necessary for online information.

`doc\pdf\:`
Various manuals (in subdirectories).

7.2 Example Programs

There are several example programs in the HALCON/C++ distribution (%HALCONEXAMPLES%\cpp\source\console\). To experiment with these examples we recommend to create a private copy in your working directory.

error_handling.cpp	demonstrates the C++ exception handling (see section 5.3 on page 43).
ia_callback.cpp	shows the usage of the HALCON image acquisition callback functionality.
matching.cpp	locates a chip on a board and measures the pins.
serialized_item.cpp	shows how to use the serialization of HALCON objects and tuples in the C++ interface.

Additional examples for using HALCON/C++ can be found in the subdirectories mfc, motif and qt of %HALCONEXAMPLES%.

7.3 Relevant Environment Variables

In the following, we briefly describe the relevant environment variables; see the Installation Guide, section A.2 on page 64, for more information, especially about how to set these variables. Note, that under Windows, all necessary variables are automatically set during the installation.

While a HALCON program is running, it accesses several files internally. To tell HALCON where to look for these files, the environment variable HALCONROOT has to be set. HALCONROOT points to the HALCON home directory. HALCONROOT is also used in the sample makefile.

The variable HALCONARCH describes the platform HALCON is used on. Please refer to section 1.1 on page 13 for more information.

The variable HALCONEXAMPLES indicates where the provided examples are installed.

If user-defined packages are used, the environment variable HALCONEXTENSIONS has to be set. HALCON will look for possible extensions and their corresponding help files in the directories given in HALCONEXTENSIONS.

Two things are important in connection with the example programs: The default directory for the HALCON operator ReadImage to look for images is %HALCONEXAMPLES%\images. If the images reside in different directories, the appropriate path must be set in ReadImage or the default image directory must be changed, using SetSystem("image_dir","..."). This is also possible with the environment variable HALCONIMAGES. The latter has to be set before starting the program.

The second remark concerns the output terminal under Linux. In the example programs, no host name is passed to OpenWindow. Therefore, the window is opened on the machine that is specified in the environment variable DISPLAY. If output on a different terminal is desired, this can be done either directly in OpenWindow(...,"hostname",...) or by specifying a host name in DISPLAY.

7.4 Creating an Executable Under Windows

Your own C++ programs that use HALCON operators must include the file `HalconCpp.h`, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ interface. Do this by adding the command

```
#include "HalconCpp.h"
```

near the top of your C++ file. In order to create an application you must link the library `halconcpp.lib` to your program.

The example projects show the necessary Visual C++ project settings.

Please assure that the stacksize is sufficient. Some sophisticated image processing problems require up to 1 MB stacksize, so make sure to set the settings of your compiler accordingly (See your compiler manual for additional information on this topic).

HALCON XL applications: If you want to use HALCON XL, you have to link the library `halconcppxl.lib` instead.

7.5 Creating an Executable Under Linux

Your own C++ programs that use HALCON operators must include the file `HalconCpp.h`, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ interface. Do this by adding the command

```
#include "HalconCpp.h"
```

near the top of your C++ file. Using this syntax, the compiler looks for `HalconCpp.h` in the current directory only. Alternatively you can tell the compiler where to find the file, giving it the `-I<pathname>` command line flag to denote the include file directory.

To create an application, you have to link two libraries to your program: The library `libhalconcpp.so` contains the various components of the HALCON/C++ interface. The library `libhalcon.so` is the HALCON library.

HALCON XL applications: If you want to use HALCON XL, you have to link the libraries `libhalconcppxl.so` and `libhalconxl.so` instead.

Please take a look at the example makefiles for suitable settings. If you call `gmake` without further arguments, the example application `matching` will be created. To create the other example applications (e.g., `error_handling`), call

```
gmake error_handling
```

You can use the example makefiles not only to compile and link the example programs but also your own programs (if placed in the subdirectory `source`). For example, to compile and link a source file called `myprogram.cpp` call

```
gmake myprogram
```

You can link the program to the HALCON XL libraries by adding `XL=1` to the make command, for example

```
gmake myprogram XL=1
```

In order to link and run applications under Linux, you have to include the HALCON library path `$HALCONROOT/lib/$HALCONARCH` in the system variable `LD_LIBRARY_PATH`.

7.6 Creating an Executable Under Mac OS X

Your own C++ programs that use HALCON operators must include the file `HalconCpp.h`, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ interface. Do this by adding the command

```
#include <HALCONCpp/HalconCpp.h>
```

near the top of your C++ file. Using this syntax, the compiler looks for `HalconCpp.h` in the HALCONCpp framework. For HALCON XL the include statement has to be adapted:

```
#include <HALCONCppxl/HalconCpp.h>
```

To create an application, you have to link the framework `HALCONCpp` to your program.

HALCON XL applications: If you want to use HALCON XL, you have to link the library framework `HALCONCppxl` instead.

Please take a look at the example Xcode projects under `/Users/Shared/Library/Application Support/HALCON-11.0/examples/cpp` for suitable project settings.

Chapter 8

Typical Image Processing Problems

This chapter shows the power the HALCON system offers to find solutions for image processing problems. Some typical problems are introduced together with sample solutions.

8.1 Thresholding an Image

Some of the most common sequences of HALCON operators may look like the following one:

```
HImage  Image("file_xyz");
HRegion Threshold        = Image.Threshold(0,120);
HRegion ConnectedRegions = Threshold.Connection();
HRegion ResultingRegions =
              ConnectedRegions.SelectShape("area","and",10,100000);
```

This short program performs the following:

- All pixels are selected with gray values between the range 0 and 120. It is also possible to use the equivalent call:

  ```
  HRegion Threshold = (Image <= 120);
  ```

- A connected component analysis is performed.
- Only regions with a size of at least 10 pixel are selected. This step can be considered as a step to remove some of the noise from the image.

8.2 Edge Detection

For the detection of edges the following sequence of HALCON/C++ operators can be applied:

```
HImage  Image("file_xyz");
HImage  Sobel = Image.SobelAmp("sum_abs",3);
HRegion Max   = Sobel.Threshold(30,255);
HRegion Edges = Max.Skeleton();
```

Some notes:

- Before applying the sobel operator it might be useful first to apply a low-pass filter to the image in order to suppress noise.
- Besides the sobel operator you can also use filters like `EdgesImage`, `PrewittAmp`, `RobinsonAmp`, `KirschAmp`, `Roberts`, `BandpassImage`, or `Laplace`.
- The threshold (in our case 30) must be selected appropriately depending on data.
- The resulting regions are thinned by a `Skeleton` operator. This leads to regions with a pixel width of 1.

8.3 Dynamic Threshold

Another way to detect edges is the following sequence:

```
HImage  Image("file_xyz");
HImage  Mean      = Image.MeanImage(11,11);
HRegion Threshold = Image.DynThreshold(Mean,5,"light");
```

Again some remarks:

- The size of the filter mask (in our case 11×11) is correlated with the size of the objects which have to be found in the image. In fact, the sizes are proportional.
- The dynamic threshold selects the pixels with a positive gray value difference of more than 5 (brighter) than the local environment (mask 11×11).

8.4 Texture Transformation

Texture transformation is useful in order to obtain specific frequency bands in an image. Thus, a texture filter detects specific structures in an image. In the following case this structure depends on the chosen filter; 16 are available for the operator `TextureLaws`.

```
HImage  Image("file_xyz");
HImage  TT   = Image.TextureLaws("ee",2,5);
HImage  Mean = TT.MeanImage(71,71);
HRegion Reg  = Mean.Threshold(30,255);
```

- The mean filter `MeanImage` is applied with a large mask size in order to smooth the "frequency" image.
- You can also apply several texture transformations and combine the results by using the operators `AddImage` and `MultImage`.

8.5 Eliminating Small Objects

The morphological operator `Opening` eliminates small objects and smoothes the contours of regions.

```
            ...
segmentation(Image,&Seg);
HRegion Circle(100,100,3.5);
HRegion Res = Seg.Opening(Circle);
```

- The term `segmentation()` is an arbitrary segmentation step that results in an array of regions (`Seg`).
- The size of the mask (in this case the radius is 3.5) determines the size of the resulting objects.
- You can choose an arbitrary mask shape.

Chapter 9

Information for Users of HALCON C++ (legacy)

HALCON 11 comes with a new HALCON/C++ interface that includes the following features:

- The API of HALCON/C++ is consistent to HALCON/.NET.
- Error handling is fully based on exceptions.
- Automatic memory management for output strings via new class `HString`.
- Fast native C++ array access to data stored in a tuple, when all elements of the tuple have the same type (e.g., array of doubles).
- Support for data classes such as `HPose`.
- Support for arrays of handle classes, e.g., multiple shape models.
- Mixing procedural and object-oriented code has been simplified.

This interface is **not compatible** with HALCON/C++ applications developed for HALCON 10 or older. However, the previous HALCON/C++ interface is still available as HALCON/C++ (legacy), so existing applications will continue to work (see section 9.1.

If you choose to migrate existing code, e.g., for reuse in a new project, please consult section 9.2.

9.1 Compiling legacy C++ applications with HALCON 11 or higher

Legacy code needs to be linked against `halconcpp10` instead of `halconcpp`.

On Windows systems:

```
/libpath:"$(HALCONROOT)\lib\$(HALCONARCH)" halconcpp10.lib
```

On Linux systems:

```
-L$(HALCONROOT)/lib/$(HALCONARCH) -lhalconcpp10 -lhalcon
```

HALCON/C++ (legacy) is not available on Mac OS X.

9.2 Converting legacy C++ code to the new HALCON/C++ interface

As the interface has been completely redesigned, it is not meaningful to provide a full list of changed classes, signatures or members. However, the important basic changes and how to address them when migrating code are listed below:

9.2.1 Change the Namespace

HALCON/C++ uses a different namespace, which needs to be adapted in your code (see section 11.1 on page 72 and section 5.1 on page 33).

```
// legacy
using namespace Halcon;
...
```

```
// new
using namespace HalconCpp;
...
```

9.2.2 Adapt existing code

- Global operators are camel-cased, e.g., `MeanImage` instead of `mean_image`, and have no return value.
- Error handling is now fully based on exceptions.
- The iconic `Array` classes are no longer available (for example, always use `HImage` instead of `HImageArray`).
- Support for data classes (e.g., `HPose`) and arrays of tools and data classes.
- New class `HString` for automatic output string management.

- Support for direct tuple access when tuple is pure (no mixed types), e.g., `double *d = tuple.DArr();`
- The class `Hobject` for procedural code has been removed. The base class `HObject` of the object-oriented API is now used instead. This class also offers members for operators that work on untyped objects such as `CountObj`, `SelectObj`, or `ConcatObj`.
- Members of `HTuple` corresponding to operators are now named according to the operator name, e.g.,

```
GetEnv            -> TupleEnvironment
ToString(pattern) -> TupleString(pattern)
Subset            -> TupleSelect
Add, Sum, Sin,... -> TupleAdd, TupleSum, TupleSin, ...
Substring         -> no longer available
Reset             -> Clear
```



```
...                                    ...
Hobject      Iconic;                   HObject Iconic;  // upper-case O
HImage       Image;                    HImage Image;
HImageArray  Images;                   HImage Images;
HRegionArray Regions;                  HRegion Regions;
HXLDArray    XLDs;                     HXLD XLDs;
char Characters[MAX_STRING];           HString Characters;
...                                    ...
read_image(&Iconic,"clip")             ReadImage(&Iconic,"clip")
long         Var;                      Hlong Var;
HTuple       Values;                   HTuple Values;
...                                    ...
Var = Values.Num();                    Var = Values.Length();
```

Limited backwards compatibility

Old signatures of global operators and old members of `HTuple` are still available when defining `HCPP_LEGACY_API`.

```
                                       #define HCPP_LEGACY_API
HTuple Values;                         HTuple Values;
...                                    ...
Values.Reset()                         Values.Reset()  // better use Clear()
```

9.2.3 Compilation

The include directory needs to be adapted:

```
$HALCONROOT/include/cpp                $HALCONROOT/include/halconcpp
```

Code using HALCON/CPP is linked against `halconcpp`, so the linkage does not have to be adapted.

Part III

Programming With HALCON/C++ (legacy)

Chapter 10

Introducing HALCON/C++ (legacy)

HALCON/C++ (legacy) is HALCON's old interface to the programming language C++. Together with the HALCON library, it allows to use the image processing power of HALCON inside C++ programs. HALCON C++ (legacy) has been the default (and only) C++ interface in HALCON up to and including version 10.

In HALCON 11, an improved HALCON/C++ interface has been introduced, which is described in part II on page 29. Users are advised to use the new C++ interface. See chapter 9 on page 61 for information on how to compile legacy C++ applications, and how to convert legacy code to the new interface.

This part is organized as follows:

- In section 10.1, we start with a first example program.
- Chapter 11 on page 71 then takes a closer look at the basics of the HALCON/C++ (legacy) interface,
- while chapter 12 on page 87 gives an overview of the classes `HImage`, etc.
- Chapter 13 on page 111 shows how to create applications based on HALCON/C++ (legacy).
- Finally, chapter 14 on page 115 presents typical image processing problems and shows how to solve them using HALCON/C++ (legacy).

10.1 A First Example

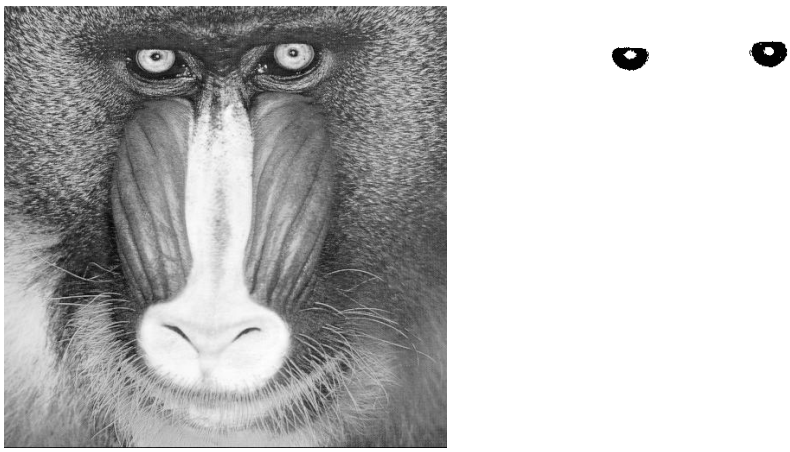


Figure 10.1: The left side shows the input image (a mandrill), and the right side shows the result of the image processing: the eyes of the monkey.

The input image is shown in figure 10.1 on the left side. The task is to find the eyes of the monkey by segmentation. The segmentation of the eyes is performed by the C++ program listed in figure 10.2, the result of the segmentation process is shown in figure 10.1 on the right side.

The program is more or less self-explaining. The basic idea is as follows: First, all pixels of the input image are selected which have a gray value of at least 128, on the assumption that the image `Mandrill` is a byte image with a gray value range between 0 and 255. Secondly, the connected component analysis is performed. The result of the HALCON operator is an array of regions. Each region is isolated in the sense that it does not touch another region according to the neighbourhood relationship. Among these regions those two are selected which correspond to the eyes of the monkey. This is done by using shape properties of the regions, the size and the anisometry.

This example shows how easy it is to integrate HALCON operators in any C++ program. Their use is very intuitive: You don't have to care about the underlying data structures and algorithms, you can ignore specific hardware requirements, if you consider e.g. input and output operators. HALCON handles the memory management efficiently and hides details from you, and provides an easy to use runtime system.

```
#include "HalconCpp.h"

main()
{
  using namespace Halcon;

  HImage  Mandrill("monkey");          // read image from file "monkey"
  HWindow w;                           // window with size equal to image

  Mandrill.Display(w);                 // display image in window
  w.Click();                           // wait for mouse click

  HRegion Bright = Mandrill >= 128;    // select all bright pixels
  HRegionArray Conn = Bright.Connection(); // get connected components

  // select regions with a size of at least 500 pixels
  HRegionArray Large = Conn.SelectShape("area","and",500,90000);

  // select the eyes out of the instance variable Large by using
  // the anisometry as region feature:
  HRegionArray Eyes = Large.SelectShape("anisometry","and",1,1.7);

  Eyes.Display(w);                     // display result image in window
  w.Click();                           // wait for mouse click
}
```

Figure 10.2: This program extract the eyes of the monkey.

Chapter 11

Basics of the HALCON/C++ (legacy) Interface

In fact, the HALCON/C++ (legacy) interface provides two different approaches to use HALCON's functionality within your C++ program: a *procedural* and an *object-oriented* approach. The procedural approach corresponds to calling HALCON operators directly as in C or HDevelop, e.g.:

```
Hobject     original_image, smoothed_image;
read_image(&original_image, "monkey");
mean_image(original_image, &smoothed_image, 11, 11);
```

In addition to the procedural approach, HALCON/C++ (legacy) allows to call HALCON operators in an object-oriented way, i.e., via a set of classes. For example, the code from above can be "translated" into:

```
HImage      original_image("monkey"), smoothed_image;
smoothed_image = original_image.MeanImage(11, 11);
```

This simple example already shows that the two approaches result in clearly different code: Besides the different operator names (procedural: small letters and underscores; object-oriented: capitals), the operator calls differ in the number and type of parameters. Furthermore, functionality may be available in different ways; for example, images can be read from files via a constructor of the class `HImage`. In general, we recommend to use the object-oriented approach. Note, however, that HDevelop can export programs only into procedural C++ code. Section 11.5 on page 84 shows how to combine procedural with object-oriented code.

In the following sections, we take a closer look at various issues regarding the use of the HALCON/C++ (legacy) interface; chapter 12 on page 87 describes the provided classes in more detail.

11.1 The Namespace Halcon

Starting with HALCON 7.1, all functions and classes of HALCON/C++ (legacy) use the namespace `Halcon` to prevent potential name conflicts with other C++ libraries. This means that the code examples on the previous page are incomplete, because the classes and operator calls cannot be used without specifying their namespace.

You can specify ("use") the namespace in three ways:

- **specifically**, by prefixing each class name or operator call with the namespace

```
Halcon::Hobject  original_image, smoothed_image;
Halcon::read_image(&original_image, "monkey");
```

- **locally**, by placing the directive `using namespace Halcon;` at the beginning of a block, e.g., at the beginning of a function:

```
int main(int argc, char *argv[])
{
  using namespace Halcon;

  Hobject     original_image, smoothed_image;
  read_image(&original_image, "monkey");
```

  Then, you can use HALCON's classes and functions without prefix inside this block.

- **globally**, by placing the directive `using` directly after including `HalconCpp.h`. Then, you don't need the prefix in your whole application.

```
#include "HalconCpp.h"
using namespace Halcon;
```

Which method is the most suitable depends on your application, more exactly on what other libraries it includes and if there are name collisions.

Please note that the namespace is not mentioned in the operator descriptions in the reference manual in order to keep it readable. Similarly, in the following sections the namespace is left out.

11.2 Calling HALCON Operators

How a HALCON operator can be called via the HALCON/C++ (legacy) interface is described in detail in the HALCON/C++ (legacy) reference manual. As an example, figure 11.1 shows parts of the entry for the operator `mean_image`.

Please note that the reference manual does not list all possible signatures of the operators. A complete list can be found in the file `include\cpp\HCPPGlobal.h`.

Below, we

- take a closer look at the parameters of an operator call (section 11.2.1)

Herror `mean_image` (Hobject Image, Hobject* ImageMean, const HTuple& MaskWidth, const HTuple& MaskHeight)

HImage `HImage::MeanImage` (const HTuple& MaskWidth, const HTuple& MaskHeight) const

HImageArray `HImageArray::MeanImage` (const HTuple& MaskWidth, const HTuple& MaskHeight) const

`Image` (input_object) ... (multichannel-)image(-array) ⇝ *HImage* (byte / int2 / uint2 / int4 / int8 / real / vector_field)

`ImageMean` (output_object) ... (multichannel-)image(-array) ⇝ *HImage* (byte / int2 / uint2 / int4 / int8 / real / vector_field)

`MaskWidth` (input_control) ..... extent.x ⇝ *HTuple (Hlong)*

`MaskHeight` (input_control) ..... extent.y ⇝ *HTuple (Hlong)*

Figure 11.1: The head and parts of the parameter section of the reference manual entry for `mean_image`.

- describe how to call operators via classes (section 11.2.2 on page 75) or via special constructors (section 11.2.3 on page 76) or destructors (section 11.2.4 on page 78)
- explain another special HALCON concept, the *tuple mode* (section 11.2.5 on page 78)

11.2.1 A Closer Look at Parameters

HALCON distinguishes two types of parameters: *iconic* and *control* parameters. *Iconic parameters* are related to the original image (images, regions, XLD objects), whereas *control parameters* are all kinds of alphanumerical values, such as integers, floating-point numbers, or strings.

A special form of control parameters are the so-called *handles*. A well-known representative of this type is the *window handle*, which provides access to an opened HALCON window, e.g., to display an image in it. Besides, handles are used when operators share complex data, e.g., the operators for shape-based matching which create and then use the model data, or for accessing input/output devices, e.g., image acquisition devices. Classes encapsulating handles are described in detail in section 12.2.3 on page 107.

Both iconic and control parameters can appear as input and output parameters of a HALCON operator. For example, the operator `mean_image` expects one iconic input parameter, one iconic output parameter, and two input control parameters (see figure 11.1); figure 11.2 shows an operator which has all four parameter types. Note how some parameters "disappear" from within the brackets if you call an operator via a class; this mechanism is described in more detail in section 11.2.2 on page 75.

An important concept of HALCON's philosophy regarding parameters is that **input parameters are not modified by an operator**. As a consequence, they are passed *by value* (e.g., `Hobject Image` in figure 11.1) or via a constant reference (e.g., `const HTuple &MaskWidth`). This philosophy also holds if an operator is called via a class, with the calling instance acting as an input parameter. Thus, in the following example code the original image is not modified by the call to `MeanImage`; the operator's result, i.e., the smoothed image, is provided via the return value instead:

Herror `find_bar_code` (Hobject Image, Hobject* SymbolRegions, const HTuple& BarCodeHandle, const HTuple& CodeType, char* DecodedDataStrings)

Herror `find_bar_code` (Hobject Image, Hobject* SymbolRegions, const HTuple& BarCodeHandle, const HTuple& CodeType, HTuple* DecodedDataStrings)

HRegionArray `HImage::FindBarCode` (const HBarCode& BarCodeHandle, const HTuple& CodeType, HTuple* DecodedDataStrings) const

HRegionArray `HBarCode::FindBarCode` (const HImage& Image, const HTuple& CodeType, HTuple* DecodedDataStrings) const

`Image` (input_object) ..... singlechannelimage ⇝ *HImage* (byte / uint2)

`SymbolRegions` (output_object) ..... region(-array) ⇝ *HRegion*

`BarCodeHandle` (input_control) ..... barcode ⇝ *HBarCode / HTuple (Hlong)*

`CodeType` (input_control) ..... string(-array) ⇝ *HTuple (char*)*

`DecodedDataStrings` (output_control) ..... string(-array) ⇝ *HTuple (char*)*

Figure 11.2: The head and parts of the parameter section of the reference manual entry for `find_bar_code`.

```
HImage      original_image("monkey"), smoothed_image;
smoothed_image = original_image.MeanImage(11, 11);
```

In contrast to input parameters, output parameters are always modified, thus they must be passed *by reference*. Note that operators expect a pointer to **an already declared variable**! For example, when calling the operator `FindBarCode` as in the following lines of code, variables of the class `HTuple` are declared before passing the corresponding pointers using the operator `&`.

```
HImage         image("barcode/ean13/ean1301");
HTuple         paramName, paramValue;
HBarCode       barcode(paramName, paramValue);
HRegionArray   code_region;
HTuple         result;

code_region = barcode.FindBarCode(image, "EAN-13", &result);
```

The above example shows another interesting aspect of output parameters: When calling operators via classes, one output parameter becomes the return value (see section 11.2.2 for more details); in the example, `FindBarCode` returns the bar code region.

Many HALCON operators accept more than one value for certain parameters. For example, you can call the operator `MeanImage` with an array of images (see figure 11.1); then, an array of smoothed images is returned. This is called the *tuple mode*; see section 11.2.5 on page 78 for more information.

Herror info_framegrabber (const HTuple& Name, const HTuple& Query, HTuple* Information, HTuple* ValueList)

Name (input_control) ..... string ⇝ *HTuple (char*)*
Query (input_control) ..... string ⇝ *HTuple (char*)*
Information (output_control) ..... string ⇝ *HTuple (char*)*
ValueList (output_control) ..... string-array ⇝ *HTuple (char*** / Hlong / double)

Figure 11.3: The head and parts of the parameter section of the reference manual entry for info_framegrabber.

String Parameters

Please note that **output parameters of the type string need special attention**: First of all, you must allocate memory for them yourself, e.g., by declaring them as character arrays; we recommend to allocate memory for at least 1024 characters for string parameters of unknown length. Secondly, you don't pass them by reference, because such parameters are pointers already. In the following example code, the operator InfoFramegrabber (see also figure 11.3) is called with two output string parameters to query the currently installed image acquisition board:

```
char        sInfo[1024], sValue[1024];

info_framegrabber(FGName, "info_boards", sInfo, sValue);
```

Note that it isn't necessary to allocate memory for output string parameters in the already mentioned *tuple mode*, i.e., when using instances of the class HTuple instead of "plain" strings (also see section 11.2.5 on page 78 and section 12.2.2 on page 104):

```
HTuple      tInfo, tValues;

info_framegrabber(FGName, "info_boards", &tInfo, &tValues);
```

11.2.2 Calling Operators via Classes

As already described in the previous section, the HALCON/C++ (legacy) reference manual shows via which classes an operator can be called. For example, FindBarCode can be called via objects of the class HImage or HBarCode (see figure 11.2 on page 74). In both cases, the corresponding input parameter (Image or BarCodeHandle, respectively) does not appear within the brackets anymore as it is replaced by the calling instance of the class (this).

There is a further difference to the procedural operator signature: The first output parameter (in the example the bar code region SymbolRegions) also disappears from within the brackets and becomes the return value instead of the error code (more about error handling can be found in section 11.3 on page 82).

```
HImage          image("barcode/ean13/ean1301");
HTuple          paramName, paramValue;
HBarCode        barcode(paramName, paramValue);
HRegionArray    code_region;
HTuple          result;

code_region = barcode.FindBarCode(image, "EAN-13", &result);
```

```
code_region = image.FindBarCode(barcode, "EAN-13", &result);
```

```
Hobject         image;
HTuple          barcode;
Hobject         code_region;
HTuple          result;

read_image(&image, "barcode/ean13/ean1301");
create_bar_code_model(HTuple(), HTuple(), &barcode);
find_bar_code(image, &code_region, barcode, "EAN-13", &result);
```

Figure 11.4: Using `FindBarCode` via `HBarCode`, via `HImage`, or in the procedural approach.

Figure 11.4 depicts code examples for the three ways to call `FindBarCode`. When comparing the object-oriented and the procedural approach, you can see that the calls to the operators `read_image` and `create_bar_code_model` are replaced by special constructors for the classes `HImage` and `HBarCode`, respectively. This topic is discussed in more detail below.

Please note that the two object-oriented methods seem to be "asymmetric": If you call `FindBarCode` via `HImage`, the reference manual seems to suggest that you must pass the *handle* instead of an instance of `HBarCode`. In fact, you can pass both a handle and a class instance, because the latter is automatically "casted" into a handle; the signature was not changed to keep the HALCON/C++ (legacy) interface backward compatible as far as possible.

11.2.3 Constructors and Halcon Operators

As can be seen in figure 11.4, the HALCON/C++ (legacy) parameter classes provide additional constructors, which are based on suitable HALCON operators. The constructors for `HImage` and `HBarCode` used in the example are based on `read_image` and `create_bar_code_model`, respectively.

Please note that in the current HALCON version constructors are provided inconsistently for the different classes. Below we take a brief look at the most important classes. A complete and up-to-date list of available constructors can be found in the corresponding header files in `%HALCONROOT%\include\cpp`.

- **Images:**
  The class `HImage` provides constructors based on the operators `read_image`, `gen_image1`, `gen_image1_extern`, and `gen_image_const`.

Please **beware of the following pitfall** when using the operators themselves via HImage: Contrary to intuition, the operators do not modify the instance they are called from; instead, the created image is the return value of the operator! Thus, after the following code the image is still uninitialized:

```
HImage         image;
image.ReadImage("barcode/ean13/ean1301");            // incorrect
```

The correct way to call ReadImage is as follows:

```
image = HImage::ReadImage("barcode/ean13/ean1301");  // correct
```

Note that this pitfall concerns all operators where HImage appears as an output parameter, e.g., GrabImage. More information about HImage can be found in section 12.1.2 on page 94.

- **Regions:**
  The class HRegion provides constructors based on operators like gen_rectangle2 or gen_circle. However, instead of the parameters of these operators, the constructors expect instances of auxiliary classes like HRectangle2 or HCircle (see section 12.3 on page 109 for more information about these classes).

  Please note that HRegion **presents the same pitfall** as HImage, i.e., operators like GenRectangle2 do not modify the calling instance of HRegion but return the created region! More information about HRegion can be found in section 12.1.1 on page 87.

- **XLDs:**
  The classes for XLDs (HXLD, HXLDCont, etc., see section 12.1.3 on page 102 for more information) do not provide constructors based on operators.

- **Windows:**
  The class HWindow provides constructors based on the operators open_window and new_extern_window. Note that the former is realized with default values for all parameters, thus becoming the default constructor, i.e., all window instances are already opened upon construction!

  Of course, you can close a window using CloseWindow and then open it again using OpenWindow. In contrast to the iconic parameter classes, you can call the "constructor-like" operator OpenWindow via an instance of HWindow in the intuitive way, i.e., the calling instance is modified; in addition the corresponding handle is returned. HWindow is described in more detail in section 12.2.3.1 on page 107.

- **Other Handle Classes:**
  The other classes encapsulating handles, e.g., HBarCode or HFramegrabber, provide constructors in a systematic way: If a class appears as an output parameter in an operator, there automatically exists a constructor based on this operator. Thus, instances of HBarCode can be constructed based on create_bar_code_model as shown in figure 11.4 on page 76, instances of HShapeModel based on create_shape_model, instances of HFramegrabber based on open_framegrabber and so on.

  In contrast to the iconic parameter classes, handle classes allow to call constructor-like operators via instances of the class in the intuitive way, i.e., the calling instance is modified. For example, you can create an instance of HBarCode with the default constructor and then initialize it using CreateBarCodeModel as follows:

```
HBarCode       barcode;
barcode.CreateBarCodeModel(HTuple(), HTuple());
```

If the instance was already initialized, the corresponding data structures are automatically destroyed before constructing and initializing them anew (see also section 11.2.4). The handle classes are described in more detail in section 12.2.3.2 on page 108.

11.2.4 Destructors and Halcon Operators

All HALCON/C++ (legacy) classes provide default destructors which automatically free the corresponding memory. For some classes, the destructors are based on suitable operators:

- **Windows:**
  The default destructor of the class `HWindow` closes the window based on `close_window`. Note that the operator itself is no destructor, i.e., you can close a window with `CloseWindow` and then open it again using `OpenWindow`.
- **Other Handle Classes:**
  The default destructors of the other classes encapsulating handles, e.g., `HShapeModel` or `HFramegrabber`, apply operators like `clear_shape_model` or `close_framegrabber`, respectively. In contrast to `close_window`, these operators cannot be called via instances of the class, as can be seen in the corresponding reference manual entries; the same holds for operators like `clear_all_shape_models`. In fact, there is no need to call these operators as you can initialize instances anew as described in section 11.2.3.

  Please note that you must not use operators like `clear_shape_model`, `clear_all_shape_models`, or `close_framegrabber` together with instances of the corresponding handle classes!

11.2.5 The Tuple Mode

As already mentioned in section 11.2.1 on page 73, many HALCON operators can be called in the so-called *tuple mode*. In this mode, you can, e.g., apply an operator to multiple images or regions with a single call. The standard case, e.g., calling the operator with a single image, is called the *simple mode*. Whether or not an operator supports the tuple mode can be checked in the reference manual. For example, take a look at figure 11.5, which shows an extract of the reference manual entry for the operator `char_threshold`: In the parameter section, the parameter `Image` is described as an `image(-array)`; this signals that you can apply the operator to multiple images at once.

If you call `char_threshold` with multiple images, i.e., with an image tuple, the output parameters automatically become tuples as well. Consequently, the parameters `Characters` and `Threshold` are described as `region(-array)` and `integer(-array)`, respectively.

The head section of the reference entry in figure 11.5 shows how simple and tuple mode are reflected in the operator's signatures. In the procedural approach, the simple and tuple mode methods of calling `char_threshold` differ only in the type of the output parameter `Threshold`: a pointer to a `long` or to a `HTuple` of `long` values, respectively. Note that the class `HTuple` can also contain arrays (tuples) of control parameters of mixed type; please refer to section 12.2.2 on page 104 for more information

Herror `char_threshold` (Hobject Image, Hobject HistoRegion, Hobject* Characters, const HTuple& Sigma, const HTuple& Percent, Hlong* Threshold)

Herror `char_threshold` (Hobject Image, Hobject HistoRegion, Hobject* Characters, const HTuple& Sigma, const HTuple& Percent, HTuple* Threshold)

HRegion `HImage::CharThreshold` (const HRegion& HistoRegion, const HTuple& Sigma, const HTuple& Percent, Hlong* Threshold) const

HRegionArray `HImageArray::CharThreshold` (const HRegion& HistoRegion, const HTuple& Sigma, const HTuple& Percent, HTuple* Threshold) const

`Image` (input_object) ..... singlechannelimage(-array) ⇝ *HImage* (byte)
`HistoRegion` (input_object) ..... region ⇝ *HRegion*
`Characters` (output_object) ..... region(-array) ⇝ *HRegion*
`Sigma` (input_control) ..... number ⇝ *HTuple (double)*
`Percent` (input_control) ..... number ⇝ *HTuple (double* / Hlong)
`Threshold` (output_control) ..... integer(-array) ⇝ *HTuple (Hlong)*

Figure 11.5: The head and parts of the parameter section of the reference manual entry for `CharThreshold`.

about this class. In contrast to the control parameters, the iconic parameters remain instances of the class `Hobject` in both modes, as this class can contain both single objects and object arrays (see also section 12.1.4 on page 102).

In the object-oriented approach, simple mode and tuple mode methods use different classes for the iconic parameters: `HImage` and `HRegion` vs. `HImageArray` and `HRegionArray` (see section 12.1.1 on page 87 and section 12.1.2 on page 94 for more information about these classes). As in the procedural approach, control parameters can be of a basic type (simple mode only) or instances of `HTuple` (simple and tuple mode).

After this rather theoretic introduction, let's take a look at example code. In figure 11.6, `char_threshold` is applied in simple mode, i.e., to a single image, in figure 11.7 to two images at once. Both examples are realized both in the object-oriented and in the procedural approach. The examples highlight some interesting points:

- **Creation and initialization of iconic arrays:**
  In the object-oriented approach, the image array can be constructed very easily by *assigning* the individual images to certain positions in the array using the well-known array operator `[]`. In the procedural approach, you must explicitly create an empty object using `gen_empty_obj` and then add the images via `concat_obj`.
- **Access to iconic objects:**
  As expected, in the object-oriented approach, the individual images and regions are accessed via the array operator `[]`; the number of objects in an array can be queried via the method `Num()`. In the procedural approach, objects must be selected explicitly using the operator `select_obj`; the number of objects can be queried via `count_obj`.

```
HImage          image("alpha1");
HRegion         region;
long            threshold;

region = image.CharThreshold(image.GetDomain(), 2, 95, &threshold);
image.Display(window);
region.Display(window);
cout << "Threshold for 'alpha1': " << threshold;
```

```
Hobject         image;
Hobject         region;
long            num;
long            threshold;

read_image(&image, "alpha1");
char_threshold(image, image, &region, 2, 95, &threshold);
disp_obj(image, window);
disp_obj(region, window);
cout << "Threshold for 'alpha1': " << threshold;
```

Figure 11.6: Using `CharThreshold` in simple mode, via `HImage`, or in the procedural approach (declaration and opening of window omitted).

- **Polymorphism of `Hobject`:** (part I)
  As already noted, instances of `Hobject` can be used both in simple and in tuple mode. In contrast, you must use different classes when switching from simple to tuple mode in the object-oriented approach.
- **Polymorphism of `Hobject`:** (part II)
  The class `Hobject` is used for all types of iconic objects. What's more, image objects can be used for parameters expecting a region, as in the call to `char_threshold` in the examples; in this case, the *domain* of the image, i.e., the region in which the pixels are "valid", is extracted automatically. In the object-oriented approach, you must extract the domain explicitly via the operator `GetDomain`.
- **Array (tuple) indices:**
  Object-oriented iconic arrays start with the index 0, the same is true for `HTuple`. In contrast, `Hobject` arrays start with the index 1!!

Most of the time you will call operators in tuple mode without noticing: As soon as you divide a region into connected components via the operator `Connection`, you end up with a `HRegionArray`– thus, any subsequent processing, e.g., morphological operations like `DilationCircle` or the calculation of the region's position using `AreaCenter` is automatically performed on all regions in the array, i.e., in tuple mode. Thus, the tuple mode is a simple mode after all!

```
HImageArray    images;
HRegionArray   regions;
HTuple         thresholds;

for (int i=1; i<=2; i++)
{
  images[i-1] = HImage::ReadImage(HTuple("alpha") + i);
}

regions = images.CharThreshold(images[0].GetDomain(), 2, 95, &thresholds);

for (int i=0; i<images.Num(); i++)
{
  images[i].Display(window);
  regions[i].Display(window);
  cout << "Threshold for 'alpha" << i+1 << "': " << thresholds[i].L();
  window.Click();
```

```
Hobject        images, image;
Hobject        regions, region;
long           num;
HTuple         thresholds;

gen_empty_obj(&images);

for (int i=1; i<=2; i++)
{
  read_image(&image, HTuple("alpha") + i);
  concat_obj(images, image, &images);
}

char_threshold(images, image, &regions, 2, 95, &thresholds);
count_obj(images, &num);

for (int i=0; i<num; i++)
{
  select_obj(images, &image, i+1);
  disp_obj(image, window);
  select_obj(regions, &region, i+1);
  disp_obj(region, window);
  cout << "Threshold for 'alpha" << i+1 << "': " << thresholds[i].L();
}
```

Figure 11.7: Using `CharThreshold` in tuple mode, via `HImageArray`, or in the procedural approach (declaration and opening of window omitted).

```
class LIntExport HException {
public:
  HException(const HException &except);
  HException(const char *f, Hlong l, const char *p, Herror e, const char *m);
  HException(const char *f, Hlong l, const char *p, const char *m);
  HException(const char *f, Hlong l, const char *p, Herror e);

  static Handler InstallHHandler(Handler proc);
  void           PrintException(void);

  static Handler handler;   /* handler in use */
  Hlong          line;      /* line number where error occured */
  char           *file;     /* file name where error occured */
  char           *proc;     /* Name of procedure/operator */
  Herror         err;       /* error number */
  char           *message;  /* error text */
};
```

Figure 11.8: Part of the declaration of the class `HException`.

11.3 Error Handling

In case of a runtime error, HALCON/C++ (legacy) by default prints a corresponding error message and terminates the program. In some applications, however, it might be useful to slacken this rule for certain errors. For example, if an application allows the user to specify an image file to read interactively, it would be inconvenient if the application terminates because the user misspelled the file name. Therefore, HALCON/C++ (legacy) allows to integrate your own error handling. The following sections describe how to do this in the

- object-oriented approach (section 11.3.1) and in the
- procedural approach (section 11.3.2).

Please note that you cannot mix object-oriented and procedural error handling.

11.3.1 Object-Oriented Approach

If a runtime error occurs in an object-oriented operator call, an instance of the class `HException` is created (see figure 11.8 for the declaration of the class). This instance contains all information concerning the error. The important members of an exception are:

`line`:	Number of the program line in which the error occurred
`file`:	Name of the file in which the error occurred
`proc`:	Name of the actual HALCON operator
`err`:	Number of the error, see below
`message`:	Error text

After the generation, the instance of `HException` is passed to a so-called *exception handler*. HALCON's default exception handler prints the corresponding error message and terminates the program.

As an alternative, you can implement and use your own exception handler. In order to act as a HALCON exception handler, a procedure must have the following signature:

```
typedef void (*Handler)(const Halcon::HException &exception);
```

You "install" your exception handler procedure via `HException`'s class method `InstallHHandler` (see figure 11.8). In case of a runtime error, HALCON then calls your procedure, passing the instance of the actual exception as a parameter.

The following example shows how to use a user-specific exception handler together with the standard C++ exception handling mechanism (`try...catch`). The corresponding program `example_errorhandling.cpp` can be found in the subdirectory `%HALCONEXAMPLES%\cpp`. It realizes the application mentioned above: You can type in image files to load; if a file does not exist, the program prints a corresponding message but continues nevertheless.

At the beginning of the program, a user-specific exception handler is installed with the following line:

```
HException::InstallHHandler(&MyHalconExceptionHandler);
```

The installed procedure simply hands the exception object to the C++ exception handling via `throw`:

```
void MyHalconExceptionHandler(const Halcon::HException& except)
{
  throw except;
}
```

The call to `ReadImage` is then encapsulated by a `try` block; a possibly ensuing exception is then evaluated in a corresponding `catch` block:

```
Herror  error_num;

try
{
  image = HImage::ReadImage(filename);
}
catch (HException &except)
{
  error_num = except.err;
  return error_num;
}
return H_MSG_TRUE;
```

11.3.2 Procedural Approach

As can be seen in the extracts of the reference manual in section 11.2 on page 72, in the procedural approach operators return a value of the type `Herror`. This value can fall into two categories: messages `H_MSG_*` and errors `H_ERR_*`.

Typically, HALCON operators return the message H_MSG_TRUE if no error occurs.

In case of an error, HALCON by default prints the corresponding error message and terminates the program. You can deactivate (and reactivate) this reaction by calling the operator set_check. The following example code checks whether a file could be opened successfully; in case of an error, it prints the corresponding error message, which can be determined with the operator get_error_text.

```
Herror         error_num;
char           message[1024];
long           file;

set_check("~give_error");
error_num = open_file("not_existing_file", "input", &file);
set_check("give_error");

if (error_num != H_MSG_TRUE)
{
  get_error_text(error_num, message);
  cout << "HALCON error " << error_num << ": " << message;
}
```

Please note that some tuple operations have no return value. Then, the described approach leads to a memory leak. Please use the object-oriented approach instead.

11.4 Memory Management

All of HALCON's classes, i.e., not only HImage, HRegion, HTuple, HFramegrabber etc., but also the class Hobject used when calling operators in the procedural approach, release their allocated memory automatically in their default destructor (see also section 11.2.4 on page 78). Furthermore, when constructing instances anew, e.g., by calling CreateBarCodeModel via an already initialized instance as mentioned in section 11.2.3 on page 76, the already allocated memory is automatically released before allocating it anew. Thus, there is no need to call the operator clear_obj in HALCON/C++ (legacy); what's more, if you do use it HALCON will complain about already released memory.

However, there are still two occasions for explicit memory management on your part: The first one was already described on page 75: For output parameters of the type string, you must allocate must alocate memory explicitely.

The second occasion is when using handles in the procedural approach: The memory allocated when creating a handle, e.g., with open_framegrabber, is only released when calling the "complementary" operator, in the example close_framegrabber — or at the end of the program.

11.5 How to Combine Procedural and Object-Oriented Code

As already noted, we recommend to use the object-oriented approach wherever possible. However, there are some reasons for using the procedural approach, e.g., if you want to quickly integrate code that is

exported by HDevelop, which can only create procedural code. Besides, currently some operators are only available in procedural form, e.g., operators creating affine transformations like `vector_to_rigid`.

The least trouble is caused by the basic control parameters as both approaches use the elementary types `long` etc. and the class `HTuple`. Iconic parameters and handles can be converted as follows:

- **Converting `Hobject` into iconic parameter classes**

```
Hobject        p_image;
read_image(&p_image, "barcode/ean13/ean1301");

HImage         o_image(p_image);
```

  Iconic parameters can be converted from `Hobject` to, e.g., `HImage` simply by calling the constructor with the procedural variable as a parameter.

- **Converting handles into handle classes**

```
HTuple         p_barcode;
create_bar_code_model(HTuple(), HTuple(), &p_barcode);

HBarCode       o_barcode;
o_barcode.SetHandle(p_barcode[0]);
o_code_region = o_barcode.FindBarCode(o_image, "EAN-13", &result);
```

  Handles cannot be converted directly via a constructor; instead, you call the method `SetHandle()` with the procedural handle as a parameter.

- **Converting handle classes into handles**

```
p_barcode = o_barcode.GetHandle();
```

  Similarly, a handle can be extracted from the corresponding class via the method `GetHandle()`. You can even omit the method, as the handle classes provide cast operators which convert them automatically into handles.

```
p_barcode = o_barcode;
```

- **Converting iconic parameter classes into `Hobject`**

```
Hobject  p_code_region = o_code_region.Id();
```

  Iconic parameters can be converted from classes like `HRegion` back into `Hobject` via the method `Id()`. In contrast to the handle classes no cast operator is provided.

- **Converting `HWindow` into a window handle**

```
long           p_window;
open_window(0, 0, width/2, height/2, 0, "visible", "", &p_window);

HWindow        o_window(0, 0, 100, 100, 0, "visible", "");

p_window = o_window.WindowHandle();
disp_obj(p_code_region, p_window);
```

  In contrast to other handles, procedural window handles cannot be converted into instances of the class `HWindow`! However, you can extract the handle from an instance of `HWindow` via the method `WindowHandle()`.

As already remarked in section 11.2.4 on page 78, you must not use operators like `clear_shape_model`, `clear_all_shape_models`, or `close_framegrabber` together with instances of the corresponding handle classes!

11.6 I/O Streams

Starting with HALCON 7.1, HALCON/C++ (legacy) no longer provides iostream operators by default because this created problems for applications that want to use the older iostream interface (i.e., that want to use <`iostream.h`> instead of <`iostream`>). Consequently, the HALCON/C++ (legacy) library now does not provide operators for either interface.

To enable backwards compatibility, the iostream operators for the class `HTuple` are now provided as inline functions in a new header file `HIOStream.h`, which can optionally be included. `HIOStream.h` uses the newer interface <`iostream`> by default, but uses the older interface <`iostream.h`> if `USE_IOSTREAM_H` is defined before `HIOStream.h` is included. Note that it may be necessary to include the statement `using namespace std;`.

To use the iostream operators, we recommend to insert the following lines of code after including `HalconCpp.h`:

```
#include "HalconCpp.h"
#include "HIOStream.h"
#if !defined(USE_IOSTREAM_H)
using namespace std;
#endif
```

Chapter 12

The HALCON Parameter Classes

12.1 Iconic Objects

The base class of the iconic parameter classes in HALCON/C++ (legacy) is the (abstract) class `HObject` which manages entries in the database, i.e., the copying or releasing of objects. The entries themselves are represented by the class `Hobject` (see also section 12.1.4 on page 102). The classes `HObject` and `Hobject` can contain all types of iconic objects. This has the advantage that important methods like `Display()` can be applied to all iconic objects in the same manner.

Three classes are derived from the root class `HObject`:

- Class `HImage` for handling images.
- Class `HRegion` for handling regions.
- Class `HXLD` for handling polygons.

These classes are described in more detail below.

12.1.1 Regions

A region is a set of coordinates in the image plane. Such a region does not need to be connected and it may contain holes. A region can be larger than the actual image format. Regions are represented by the so-called runlength coding in HALCON. The class `HRegion` represents a region in HALCON/C++ (legacy). Besides those operators that can be called via `HRegion` (see also section 11.2.2 on page 75), `HRegion` provides the following member functions:

- `HRegion(void)`
  Default constructor. It creates an empty region, i.e., the area of this region is zero. Not all operators can handle the empty region as input, e.g. some shape property operators.
- `HRegion(const HDChord &line)`
  Constructing a region from a chord. A chord is a horizontal line.

- `HRegion(const HDPoint2D &point)`
  Constructing a region from a discrete 2-dimensional point.
- `HRegion(const HRectangle1 &rect)`
  Constructing a region from a rectangle parallel to the coordinate axis. The coordinates do not need to be discrete.
- `HRegion(const HRectangle2 &rect)`
  Constructing a region from an arbitrarily oriented rectangle. The coordinates do not need to be discrete.
- `HRegion(const HCircle &circle)`
  Constructing a region from a circle. The radius and center do not need to be discrete.
- `HRegion(const HEllipse &ellipse)`
  Constructing a region from an arbitrarily oriented ellipse. The radii and center do not need to be discrete.
- `HRegion(const char *file)`
  Constructing a region by reading the representation from file. This file can be generated by the member function `WriteRegion`.
- `HRegion(const HRegion &reg)`
  Copy constructor.
- `HRegion &operator = (const HRegion &reg)`
  Assignment operator.
- `~HRegion(void)`
  Destructor.
- `void Display(const HWindow &w) const`
  Output of the region in a window.
- `HRegion  operator * (double scale) const`
  Zooming the region by an arbitrary factor. The center of scaling is the origin $(0, 0)$.
- `HRegion  operator >> (double radius) const`
  `HRegion &operator >>= (double radius)`
  Erosion of the region with a circle of radius `radius`, see reference manual entry of `erosion_circle`.
- `HRegion  operator << (double radius) const`
  `HRegion &operator <<= (double radius)`
  Dilation of the region with a circle of radius `radius`, see reference manual entry `dilation_circle`.
- `HRegion  operator + (const HDPoint2D &point) const`
  `HRegion &operator += (const HDPoint2D &point)`
  Translating the region by a 2-dimensional point.
- `HRegion &operator ++ (void)`
  Dilation of the region with a cross containing five points.

- `HRegion operator + (const HRegion &reg) const`
  `HRegion &operator += (const HRegion &reg)`
  Minkowsky addition of the region with another region, see reference manual entry of `minkowski_add1`.

- `HRegion operator - (const HRegion &reg) const`
  `HRegion &operator -= (const HRegion &reg)`
  Minkowsky subtraction of the region with another region, see reference manual entry of `minkowski_sub1`.

- `HRegion &operator -- (void)`
  Erosion of the region with a cross containing five points.

- `HRegion operator ~ (void) const`
  Complement of the region, see reference manual entry of `complement`.

- `HRegion operator ! (void) const`
  Transpose the region at the origin, see reference manual entry of `transpose_region`.

- `HRegion operator & (const HRegion &reg) const`
  `HRegion &operator &= (const HRegion &reg)`
  Intersection of the region with another region, see reference manual entry of `intersection`.

- `HRegion operator | (const HRegion &reg) const`
  `HRegion &operator |= (const HRegion &reg)`
  Union of the region with another region, see reference manual entry of `union2`.

- `HRegion operator / (const HRegion &reg) const`
  `HRegion &operator /= (const HRegion &reg)`
  Subtract another region from the region, see reference manual entry of `difference`.

- `HBool operator == (const HRegion &reg) const`
  Boolean test if two regions are identical, see reference manual entry of `test_equal_region`.

- `HBool operator >= (const HRegion &reg) const`
  `HBool operator > (const HRegion &reg) const`
  `HBool operator <= (const HRegion &reg) const`
  `HBool operator < (const HRegion &reg) const`
  Boolean test if another region is included in the region by using the subset of the corresponding coordinates.

- `double Phi(void) const`
  Orientation of the region by using the angle of the equivalent ellipse, see reference manual entry of `elliptic_axis`.

- `double Ra(void) const`
  Length of the major axis of the equivalent ellipse of the region, see reference manual entry of `elliptic_axis`.

- `double Rb(void) const`
  Length of the minor axis of the equivalent ellipse of the region, see reference manual entry of `elliptic_axis`.

- `long Area(void) const`
  Area of the region, i.e., number of pixels, see reference manual entry of `area_center`.
- `double X(void) const`
  `double Y(void) const`
  Center point of the region, see reference manual entry of `area_center`.
- `double Contlength(void) const`
  Length of the contour of the region, see reference manual entry of `contlength`.
- `double Compactness(void) const`
  Compactness of the actual region, see reference manual entry of `compactness`.
- `double Anisometry(void) const`
  `double Bulkiness(void) const`
  `double StructureFactor(void) const`
  Shape factors, see reference manual entry of `eccentricity`.
- `double M11(void) const`
  `double M20(void) const`
  `double M02(void) const`
  `double Ia(void) const`
  `double Ib(void) const`
  Moments of the region, see reference manual entry of `moments_region_2nd`.
- `HRectangle1 SmallestRectangle1(void) const`
  Smallest surrounding rectangle parallel to the coordinate axis, see reference manual entry of `smallest_rectangle1`.
- `HBool In(const HDPoint2D &p) const`
  Boolean test if a point is inside a region, see reference manual entry of `test_region_point`.
- `HBool IsEmpty(void) const;`
  Boolean test if the region is empty, i.e., the area of the region is zero.

A program shows the power of the class `HRegion`, see figure 12.1.

First, an aerial image (`mreut.png`) is read from a file. All pixels with a gray value ≥ 190 are selected. This results in one region (`region`).

This region is transformed by the next steps: All holes in the region are filled (`FillUp`), small parts of the region are eliminated by two morphological operations, first an erosion, a kind of shrinking the region, followed by a dilation, a kind of enlarging the region. The last step is the zooming of the region. For that the region is first shifted by a translation vector $(-100, -150)$ to the upper left corner and then zoomed by the factor two. Figure 12.2 shows the input image and the result of the opening operation.

12.1.1.1 Region Arrays

The class `HRegionArray` serves as container class for regions. Besides those operators that can be called via `HRegionArray` (see also section 11.2.2 on page 75), `HRegionArray` provides the following member functions:

```
#include "HalconCpp.h"
using namespace Halcon;

main ()
{
  HImage     image("mreut");              // Reading an aerial image
  HRegion    region = image >= 190;       // Calculating a threshold
  HWindow    w;                           // Display window
  w.SetColor("red");                      // Set color for regions
  region.Display(w);                      // Display the region
  HRegion    filled = region.FillUp();    // Fill holes in region
  filled.Display(w);                      // Display the region
  // Opening: erosion followed by a dilation with a circle mask
  HRegion    open =  (filled >> 4.5) << 4.5;
  w.SetColor("green");                    // Set color for regions
  open.Display(w);                        // Display the region
  HDPoint2D  trans(-100,-150);            // Vector for translation
  HRegion    moved  = open + trans;       // Translation
  HRegion    zoomed = moved * 2.0;        // Zooming the region
}
```

Figure 12.1: Sample program for the application of the class `HRegion` .

Figure 12.2: On the left the input image (`mreut.png`), and on the right the region after the opening (`open`).

- `HRegionArray(void)`
  Constructor for an empty array (`Num()` is 0).
- `HRegionArray(const HRegion &reg)`
  Constructor with a single region.

- `HRegionArray(const HRegionArray &arr)`
  Copy constructor.
- `~HRegionArray(void)`
  Destructor.
- `HRegionArray &operator = (const HRegionArray &arr)`
  Assignment operator.
- `long Num(void)`
  Number of regions in the array, largest index is `Num()` $-\ 1$.
- `HRegion const &operator [] (long index) const`
  Reading the element i of the array. The index is in the range $0 \ldots$ `Num()` $-\ 1$.
- `HRegion &operator [] (long index)`
  Assigning a region to the element i of the array. The index `index` can be $\geq$ `Num()`.
- `HRegionArray operator () (long min, long max) const`
  Selecting a subset between the lower `min` and upper `max` index.
- `HRegionArray &Append(const HRegion &reg)`
  Appending another region to the region array.
- `HRegionArray &Append(const HRegionArray &reg)`
  Appending another region array to the region array.
- `void Display(const HWindow &w) const`
  Display the regions of the array in a window.
- `HRegionArray operator << (double radius) const`
  Applying a dilation to all regions using a circular mask, see reference manual entry of `dilation_circle`.
- `HRegionArray operator >> (double radius) const`
  Applying an erosion to all regions using a circular mask, see reference manual entry of `erosion_circle`.
- `HRegionArray operator + (const HRegion &reg) const`
  Applying the Minkowsky addition to all regions using another region as mask, see reference manual entry of `minkowski_add1`.
- `HRegionArray operator - (const HRegion &reg) const`
  Applying the Minkowsky subtraction to all regions using another region as mask, see reference manual entry of `minkowski_sub1`.
- `HRegionArray operator ~ (void) const`
  Applying the complement operator to each region of the array, see reference manual entry of `complement`.
- `HRegionArray operator & (const HRegionArray &reg) const`
  Intersection of each region of the actual array with the union of `reg`, see reference manual entry of `intersection`.

- `HRegionArray operator | (const HRegionArray &reg) const`
  Union of each region in the actual array with the union of `reg`, see reference manual entry of `union2`.
- `HRegionArray operator / (const HRegionArray &reg) const`
  Difference of each region in the actual array with the union of `reg`, see reference manual entry of `difference`.

Most HALCON operators expecting a region for an input parameter accept an instance of `HRegionArray`, e.g. `Union1`, `Intersection`, `Difference`, etc. The constructor instantiating the region array `HRegionArray` from a single region `HRegion` makes it possible to handle operators expecting a single region: Without changing the data structure a `HRegionArray` can be used as input parameter even in the case of a single region.

Figure 12.3 shows a short example how to use the class `HRegionArray`.


```
#include "HalconCpp.h"
using namespace Halcon;

main ()
{
  HImage        image("control_unit");       // Reading an image from file
  // Segmentation by regiongrowing
  HRegionArray  regs = image.Regiongrowing(1,1,4,100);
  HWindow       w;                           // Display window
  w.SetColored(12);                          // Set colors for regions
  regs.Display(w);                           // Display the regions
  HRegionArray  rect;                        // New array
  for (long i = 0; i < regs.Num(); i++)      // For all regions in array
  { // Test size and shape of each region
    if ((regs[i].Area() > 1000) && (regs[i].Compactness() < 1.5))
      rect.Append(regs[i]);                  // If test true, append region
  }
  image.Display(w);                          // Display the image
  rect.Display(w);                           // Display resulting regions
}
```

Figure 12.3: Sample program for use of the class `HRegionArray` .

The first step is to read an image. In this case it shows a control unit in a manufacturing environment, see figure 12.4 on the left side. By applying a regiongrowing algorithm from the HALCON library the image is segmented into regions. Each region inside the resulting region array `regs` is now selected according to its size and its compactness. Each region of a size larger than 1000 pixels and of a compactness value smaller than 1.5 is appended to the region array `rect`. After the processing of the `for` loop only the regions showing on the right side of figure 12.4 are left.

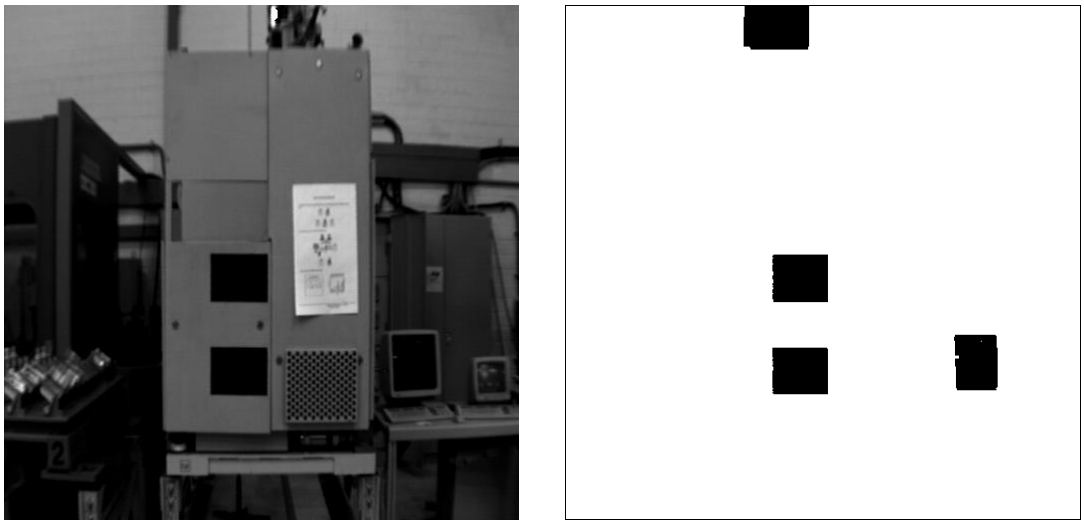


Figure 12.4: On the left side the input image (`fabrik.png`), and on the right side the selected rectangles.

12.1.2 Images

There is more to HALCON images than just a matrix of pixels: In HALCON, this matrix is called a *channel*, and images may consist of one or more such channels. For example, gray value images consist of a single channel, color images of three channels. Channels can not only contain the standard 8 bit pixels (pixel type `byte`) used to represent gray value images, HALCON allows images to contain various other data, e.g. 16 bit integers (type `int2`) or 32 bit floating point numbers (type `real`) to represent derivatives. Besides the pixel information, each HALCON image also stores its so-called *domain* in form of a HALCON region. The domain can be interpreted as a region of interest, i.e., HALCON operators (with some exceptions) restrict their processing to this region.

12.1.2.1 Image Objects

The class `HImage` is the root class for all derived image classes. By using the class `HImage` all different pixel types can be handled in a unique way (polymorphism). The class `HImage` is not virtual, thus it can be instantiated. Besides those operators that can be called via `HRegion` (see also section 11.2.2 on page 75), `HRegion` provides the following member functions:

- `HImage(void)`
  Default constructor, empty image.
- `HImage(const char *file)`
  Constructing an image by reading from a file, see reference manual entry of `read_image`.
- `HImage(int width, int height, const char *type)`
  Constructing an image of a defined size and a specific pixel type, see reference manual entry of `gen_image_const`.

- `HImage(void *ptr, int width, int height, const char *type)`
  Constructing an image of a defined size and a specific pixel type by copying memory, see reference manual entry of `gen_image1`.
- `HImage(const HImage &image)`
  Copy constructor.
- `virtual ~HImage(void)`
  Destructor.
- `HImage &operator = (const HImage &arr)`
  Assignment operator.
- `virtual const char *PixType(void) const`
  Return the pixel type of the image, see reference manual entry of `get_image_type`.
- `int Width(void) const`
  Return the width of the image, see reference manual entry of `get_image_size`.
- `int Height(void) const`
  Return the height of the image, see reference manual entry of `get_image_size`.
- `HPixVal GetPixVal(int x, int y) const`
  Access a pixel value via the (x, y) coordinates, see reference manual entry of `get_grayval`.
- `HPixVal GetPixVal(long k) const`
  Linear access of a pixel value.
- `virtual void SetPixVal(int x, int y, const HPixVal &val)`
  Set the pixel value via the (x, y) coordinates, see reference manual entry of `set_grayval`.
- `virtual void SetPixVal(long k, const HPixVal &val)`
  Set the pixel value by linear access.
- `virtual void Display(const HWindow &w) const`
  Display an image in a window.
- `HImage  operator & (const HRegion &reg) const`
  Reduce the domain of an image, see reference manual entry of `reduce_domain`.
- `HImage  operator + (const HImage &add) const`
  Adding two images, see reference manual entry of `add_image`.
- `HImage  operator - (const HImage &sub) const`
  Subtracting two images, see reference manual entry of `sub_image`.
- `HImage  operator * (const HImage &mult) const`
  Multiplication of two images, see reference manual entry of `mult_image`.
- `HImage  operator - (void) const`
  Inverting the values of the image, see reference manual entry of `invert_image`.
- `HImage  operator + (double add) const`
  `HImage  operator - (double sub) const`
  `HImage  operator * (double mult) const`

`HImage operator / (double div) const`
Arithmetic operators, see reference manual entry of `scale_image`.

- `HRegion operator >= (const HImage &image) const`
  `HRegion operator <= (const HImage &image) const`
  Selecting all pixel with gray values brighter than or equal to (or darker than or equal to, respectively) those of the input image, see reference manual entry of `dyn_threshold`.

- `HRegion operator >= (double thresh) const`
  `HRegion operator <= (double thresh) const`
  `HRegion operator == (double thresh) const`
  `HRegion operator != (double thresh) const`
  Selecting all pixel with gray values brighter than or equal to (or darker than or equal to, or equal to, or not equal to, respectively) a threshold, see reference manual entry of `threshold`.

Figure 12.5 gives an example of the use of the class `HImage`.

```
#include "HalconCpp.h"
using namespace Halcon;
#include "HIOStream.h"
#if !defined(USE_IOSTREAM_H)
using namespace std;
#endif

main ()
{
  HImage   image("mreut");                    // Aerial image
  HWindow  w;                                 // Output window
  image.Display(w);                           // Display image
  // Returning the size of the image
  cout << "width  = " << image.Width();
  cout << "height = " << image.Height() << endl;
  // Interactive drawing of a region by using the mouse
  HRegion  mask = w.DrawRegion();
  // Reduce the domain of the image to the mask
  HImage   reduced = image & mask;
  w.ClearWindow();                            // Clear the window
  reduced.Display(w);                         // Display the reduced image
  // Applying the mean filter in the reduced image
  HImage   mean = reduced.MeanImage(61,61);
  mean.Display(w);
  HRegion  reg = bild >= (mean + 3);
  reg.Display(w);
}
```

Figure 12.5: Sample program for the use of the class `HImage` .

The example starts by reading a byte image from a file. The aim is to extract bright parts from the image. The used filter and the segmentation process itself is applied only in a pre-chosen part of the image in order to accelerate the runtime. This part is selected by drawing an arbitrary region with the mouse. This

Figure 12.6: On the left side the input image (`mreut.png`), and on the right side the segmented regions in the selected image domain.

region `mask` serves as input for reducing the domain of the original image (operator `&`). The mean filter with a mask size of 61×61 is applied to the resulting region `reduced`. Bright pixels are selected by applying the operator `>=`. All pixels brighter than the filtered part of the image `reduced` $+3$ are selected. Figure 12.6 shows the result of the sample program in figure 12.5.

12.1.2.2 Pixel Values

The class `HPixVal` is used for accessing the pixel values of the class `HImage`. Gray values can be set and returned independent of their types:

- `HPixVal(void)`
  Default constructor.
- `HPixVal(const HComplex &Val)`
  Constructing a pixel value from a complex number.
- `HPixVal(int Val)`
  Constructing a pixel value from an integer (`int`).
- `HPixVal(long Val)`
  Constructing a pixel value from a long (`long`).
- `HPixVal(HByte Val)`
  Constructing a pixel value from a byte (`byte`).
- `HPixVal(double Val)`
  Constructing a pixel value from a double (`double`).

```
#include "HalconCpp.h"
#include "HIOStream.h"
#if !defined(USE_IOSTREAM_H)
using namespace std;
#endif
using namespace Halcon;

main ()
{
  HByteImage  in("mreut");         // Aerial image
  HWindow w;                       // Output window
  in.Display(w);                   // Displaying the image
  HByteImage out = in;             // Copying the image
  int  width  = out.Width();       // Width of the image
  int  height = out.Height();      // Height of the image
  long end    = width * height;    // Number of pixel of the image

  // 1. run: linear accessing
  for (long k = 0; k < end; k++) {
    int pix = in.GetPixVal(k);     // Reading the pixel
    out.SetPixVal(k,255-pix);      // Setting the pixel
  }
  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();

  // 2. run: accessing the image via the coordinates (x,y)
  for (int y=0; y<height; y++) {
    for (int x=0; x<width; x++) {
      int pix = in.GetPixVal(x,y); // Reading the pixel
      out.SetPixVal(x,y,255-pix);  // Setting the pixel
    }
  }
  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();
}
```

Figure 12.7: Sample program for the use of the class `HPixVal`.

- `HPixVal(const HPixVal &Val)`
  Copy constructor.
- `HPixVal &operator = (const HPixVal &grey)`
  Assignment operator.
- `operator HByte(void) const`
  Converting a pixel value to byte $(0 \ldots 255)$.

- `operator int(void) const`
  Converting a pixel value to `int`.
- `operator long(void) const`
  Converting a pixel value to `long`.
- `operator double(void) const`
  Converting a pixel value to `double`.
- `operator HComplex(void) const`
  Converting a pixel value to `Complex`.

The handling of the class `HPixVal` is explained by an example in figure 12.7 which inverts an input image. The input image is a byte image. First, a copy is generated and the image size is determined. In the first run the pixels are accessed linearly. In the second run the pixel are accessed via the (x, y)-ccordinates.

12.1.2.3 Image Arrays

The same way which was used to define arrays of regions is used to obtain arrays of images. The class is named `HImageArray` and contains the following member functions (in addition to the operators):

- `HImageArray(void)`
  Default constructor: empty array, no element.
- `HImageArray(const HImage &reg)`
  Constructing an image array from a single image.
- `HImageArray(const HImageArray &arr)`
  Copy constructor.
- `~HImageArray(void)`
  Destructor.
- `HImageArray &operator = (const HImageArray &arr)`
  Assignment operator.
- `long Num(void) const`
  Returning the number of elements in the array.
- `HImage const &operator [] (long index) const`
  Reading the element i of the array. The index is in the range $0 \ldots$ `Num()` $- 1$.
- `HImage &operator [] (long index)`
  Assigning an image to the element i of the array. The index `index` can be $\geq$ `Num()`.
- `HImageArray operator () (long min, long max)`
  Selecting a subset between the lower `min` and upper `max` index.
- `HImageArray &Append(const HImage &image)`
  Appending another image to the image array.
- `HImageArray &Append(const HImageArray &images)`
  Appending another image array to the image array.

```
#include "HalconCpp.h"
#include "HIOStream.h"
#if !defined(USE_IOSTREAM_H)
using namespace std;
#endif
using namespace Halcon;

main ()
{
  HByteImage  in("mreut");         // Aerial image
  HWindow w;                       // Output window
  in.Display(w);                   // Displaying the image
  HImageByte out = in;             // Copying the image
  int  width  = out.Width();       // Width of the image
  int  height = out.Height();      // Height of the image
  long end    = width * height;    // Number of pixel of the image

  // 1. run: linear accessing
  for (long k = 0; k < end; k++)
    out[k] = 255 - in[k];          // Reading and setting the pixel

  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();

  // // 2. run: accessing the image via the coordinates (x,y)
  for (int y=0; y<height; y++)
    for (int x=0; x<width; x++)
      out(x,y) = 255 - out(x,y);   // Reading and setting the pixel

  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();
}
```

Figure 12.8: Sample program for accessing a pixel value using the class `HByteImage`.

12.1.2.4 Byte Images

For each pixel type, there exists a corresponding image class derived from `HImage`, e.g., `HByteImage` for the pixel type `byte` (standard 8 bit pixels) or `HInt2Image` for the pixel type `int2` (unsigned 16 bit pixels). The most important derived class is naturally `HByteImage`, as this pixel type still covers the majority of all applications in the field of image processing. The advantage of the class `HByteImage` in comparison to the class `HImage` is the simplified access to the pixel values. This is because the class `HPixVal` is not necessary. Besides the member functions of `HImage`, the class `HByteImage` contains the following extensions:

- `HByteImage(void)`
  Default constructor.

- `HByteImage(const char *file)`
  Constructing a byte image by reading a file.
- `HByteImage(int width, int height)`
  Constructing an empty byte image of a given size.
- `HByteImage(HByte *ptr, int width, int height)`
  Constructing a byte image by copying memory.
- `HByteImage(const HByteImage &image)`
  Copy constructor.
- `virtual ~HByteImage(void)`
  Destructor.
- `HByte &operator[] (long k)`
  Setting a pixel value by linear accessing.
- `HByte operator[] (long k) const`
  Reading a pixel value by linear accessing.
- `HByte &operator() (long k)`
  Setting a pixel value by linear accessing.
- `HByte operator() (long k) const`
  Reading a pixel value by linear accessing.
- `HByte &operator()(int x, int y)`
  Setting a pixel value by accessing it via (x, y) coordinates.
- `HByte operator()(int x, int y) const`
  Reading a pixel value by accessing it via (x, y) coordinates.
- `HByteImage operator & (int i)`
  Applying the logical "and"-operation on each pixel with `i`.
- `HByteImage operator << (int i)`
  Applying a left-shift on each pixel with `i`.
- `HByteImage operator >> (int i)`
  Applying a right-shift on each pixel with `i`.
- `HByteImage operator ~ (void)`
  Complement of each pixel.
- `HByteImage operator & (HByteImage &ima)`
  Pixel by pixel logical "and"-operation of two images.
- `HByteImage operator | (HByteImage &ima)`
  Pixel by pixel logical "or"-operation of two images.
- `HByteImage operator ^ (HByteImage &ima)`
  Pixel by pixel logical "xor"-operation of two images.

The advantage of the class `HByteImage` can be seen when accessing each pixel, see figure 12.8. The class `HPixVal` is not necessary in this example. Furthermore, the member functions `GetPixVal` and

SetPixVal are not used. HByteImage allows to access pixel values in a notation like in the programming language C. The result of the example in figure 12.8 is basically the same as in the example in figure 12.7 on page 98. The program in figure 12.8 is shorter, easy to read, and has a better runtime performance.

12.1.3 XLD Objects

XLD is the abbreviation for e**X**tended **L**ine **D**escription. This is a data structure used for describing areas (e.g., arbitrarily sized regions or polygons) or any closed or open contour, i.e., also lines. In contrast to regions, which represent all areas at pixel precision, XLD objects provide subpixel precision. There are two basic XLD structures: contours and polygons.

Similarly to images, HALCON/C++ (legacy) provides both a base class HXLD and a set of specialized classes derived from HXLD, e.g., HXLDCont for contours or HXLDPoly for polygons. For all classes there exists a corresponding container class, e.g., HXLDArray.

In contrast to the classes described in the previous sections, the XLD classes provide only member functions corresponding to HALCON operators (see also section 11.2.2 on page 75).

12.1.4 Low-Level Iconic Objects

As could be seen in the examples in chapter 11 on page 71, when calling operators in the procedural approach, the class Hobject is used for all iconic parameters, be it an image, a region, or even an image array. In fact, the class Hobject is HALCON's basic class for accessing the internal data management, i.e., it handles the keys of the database. Furthermore, Hobject serves as the basis for the class HObject and the derived classes, e.g., HImage.

The class Hobject has the following member functions:

- `Hobject(void)`
  Default constructor.
- `Hobject(const Hobject &obj)`
  Copy constructor.
- `virtual ~Hobject(void)`
  Destructor.
- `Hobject &operator = (const Hobject &obj)`
  Assignment operator.
- `void Reset(void)`
  Freeing the memory and resetting the corresponding database key.

As noted above, an instance of Hobject can also contain a tuple (array) of iconic objects. Unfortunately, Hobject provides no special member functions to add objects or select them; instead, you must use the operators gen_empty_obj, concat_obj, select_obj, and count_obj as described in section 11.2.5 on page 78.

12.2 Control Parameters

HALCON/C++ (legacy) can handle different types of alphanumerical control parameters for HALCON operators:

- discrete numbers (`long`),
- floating point numbers (`double`), and
- strings (`char *`).

A special form of control parameters are the so-called *handles*, which provide access to more complex data structures like windows, image acquisition connections, or models for shape-based matching. Internally, handles are almost always represented by discrete numbers (`long`). For handles there exist corresponding classes, which are described in section 12.2.3 on page 107.

With the class `HTuple`, HALCON/C++ (legacy) provides a container class for control parameters. What's more, `HTuple` is polymorphic, i.e., it can also contain arrays of control parameters of mixed type. To realize this, the auxiliary class `HCtrlVal` is introduced, which is described in the next section.

12.2.1 The Basic Class for Control Parameters

The class `HCtrlVal` serves as the basis for the class `HTuple` and is normally hidden from the user because it is only used temporarily for type conversion. The main point is that it can contain the three elementary types of control parameters, i.e., discrete numbers (`long`), floating point numbers (`double`), and strings (`char *`). `HCtrlVal` provides the following member functions:

- `HCtrlVal(void)`
  Default constructor.
- `HCtrlVal(long l)`
  Constructing a value from `long`.
- `HCtrlVal(int l)`
  Constructing a value from `int`.
- `HCtrlVal(double d)`
  Constructing a value from `double`.
- `HCtrlVal(const char *s)`
  Constructing a value from `char *`.
- `HCtrlVal(const HCtrlVal &v)`
  Copy constructor.
- `~HCtrlVal(void)`
  Destructor.
- `HCtrlVal& operator = (const HCtrlVal &v)`
  Assignment operator.
- `int ValType() const`
  Type of a value (1: `long`, `int`; 2: `float`, `double`; 4: `string`).

- `operator int(void) const`
  Conversion to `int`.
- `operator long(void) const`
  Conversion to `long`.
- `operator double(void) const`
  Conversion to `double`.
- `operator const char*(void) const`
  Conversion to `char *`.
- `double D() const`
  Accessing a value and conversion to `double`.
- `long L() const`
  Accessing a value and conversion to `long`.
- `int I() const`
  Accessing a value and conversion to `int`.
- `const char *S() const`
  Accessing a value and conversion to `char *`.
- `HCtrlVal operator + (const HCtrlVal &val) const`
  Adding two values.
- `HCtrlVal operator - (const HCtrlVal &val) const`
  Subtracting two values.
- `HCtrlVal operator * (const HCtrlVal &val) const`
  Multiplying two values.
- `HCtrlVal operator / (const HCtrlVal &val) const`
  Division of two values.

12.2.2 Tuples

The class `HTuple` is built upon the class `HCtrlVal`; it implements an array of dynamic length for instances of the class `HCtrlVal`. The default constructor constructs an empty array (`Num() == 0`). This array can dynamically be expanded via assignments. The memory management, i.e., reallocation, freeing, is also managed by the class. The index for accessing the array is in the range between 0 and `Num()` $- 1$.

The following member functions reflect only a small portion of the total. For further information please refer to the file `HTuple.h` in `%HALCONROOT%\include\cpp`.

- `HTuple(void)`
  Default constructor. Constructs an empty tuple.
- `HTuple(long l)`
  Constructing an array of length 1 from a discrete number `long` at index position 0.

- `HTuple(int l)`
  Constructing an array of length 1 from a discrete number converted to the internal type `long` at index position 0.
- `HTuple(HCoord c)`
  Constructing an array of length 1 from a coordinate at index position 0.
- `HTuple(double d)`
  Constructing an array of length 1 from a floating number `double` at index position 0.
- `HTuple(const char *s)`
  Constructing an array of length 1 from a string `char*` at index position 0.
- `HTuple(const HTuple &t)`
  Copying a tuple.
- `HTuple(int length, const HTuple \&value)`
  Constructing an array of the specified length with a constant value, similar to the operator `tuple_gen_const`.
- `~HTuple()`
  Destructor.
- `HTuple &operator = (const HTuple& in)`
  Assignment operator.
- `HTuple Sum(void) const`
  Adding all elements in case they are numbers, similar to the operator `tuple_sum`.
- `HCtrlVal &operator [] (int i)`
  Setting the $i-$th element.
- `HCtrlVal operator [] (int i) const`
  Reading the $i-$th element.
- `HTuple operator + (const HTuple &val) const`
  Adding two tuples element by element, similar to the operator `tuple_add`. The arrays have to be of the same size.
- `HTuple operator + (double &val) const`
  `HTuple operator + (int &val) const`
  Adding a number to each element of the tuple, similar to the operator `tuple_add`.
- `HTuple operator - (const HTuple &val) const`
  Subtracting two tuples element by element, similar to the operator `tuple_sub`. The arrays have to be of the same size.
- `HTuple operator - (double &val) const`
  `HTuple operator - (int &val) const`
  Subtracting a number from each element of the tuple, similar to the operator `tuple_sub`.
- `HTuple operator * (const HTuple &val) const`
  Multiplying two tuples element by element, similar to the operator `tuple_mult`. The arrays have to be of the same size.

- `HTuple operator * (double &val) const`
  `HTuple operator * (int &val) const`
  Multiplying a number with each element of the tuple, similar to the operator `tuple_mult`.
- `HTuple operator / (const HTuple &val) const`
  Division of two tuples element by element, similar to the operator `tuple_div`. The arrays have to be of the same size.
- `HTuple operator / (double &val) const`
  `HTuple operator / (int &val) const`
  Division of each element of the tuple by a number, similar to the operator `tuple_div`.
- `HTuple Concat(const HTuple &t) const`
  Concatenating two tuples, similar to the operator `tuple_concat`.

```
#include "HalconCpp.h"
using namespace Halcon;
#include "HIOStream.h"
#if !defined(USE_IOSTREAM_H)
using namespace std;
#endif

main ()
{
  HTuple  t;
  cout << t.Num() << '\n';             // The length of the tuple is 0
  t[0] = 0.815;                         // Assigning values to the tuple
  t[1] = 42;
  t[2] = "HAL";
  cout << t.Num() << '\n';             // The length of the tuple is 3
  cout << "HTuple = " << t << '\n';    // Using the << operator
  double d = t[0];                      // Accessing the tuple, if the
  long   l = t[1];                      // the types of the elements
  const char  *s = t[2];                // are known
  // Accessing the tuple, if the types of the elements are known
  printf("Values: %g %ld %s\n",t[0].D(),t[1].L(),t[2].S());
}
```

Figure 12.9: Sample for the use of the class `HTuple` .

Figure 12.9 shows a short sample how to use tuples, i.e., the class `HTuple`: The default constructor generates an empty tuple. By assigning values to the tuple it is automatically expanded, and the data types of the values are also stored. For accessing the tuple the normal array notation can be used. If the data type of a value is not known in advance, an explicit type conversion has to be performed, see figure 12.9.

12.2.3 Classes Encapsulating Handles

The perhaps most prominent handle class is `HWindow`, which is described in section 12.2.3.1. Starting with version 6.1, HALCON/C++ (legacy) also provides classes for handles to files or functionality like access to image acquisition devices, measuring, or shape-based matching. See section 12.2.3.2 on page 108 for an overview.

12.2.3.1 Windows

The class `HWindow` provides the management of HALCON windows in a very convenient way. The properties of HALCON windows can be easily changed, images, regions, and polygons can be displayed, etc. Besides those operators that can be called via `HWindow` (see also section 11.2.2 on page 75), `HWindow` provides the following member functions:

- ```
  HWindow(int Row=0, int Column=0,
          int Width=-1, int Height=-1,
          int Father = 0, const char *Mode = "",
          const char *Host = "")
  ```
  Default constructor. The constructed window is opened.

- `~HWindow(void)`
  Destructor. This closes the window.

- `void Click(void) const`
  Waiting for a mouse click in the window.

- `HDPoint2D GetMbutton(int *button) const`
  `HDPoint2D GetMbutton(void) const`
  Waiting for a mouse click in the window. It returns the current mouse position in the window and the number of the button that was pressed, see the reference manual entry of `get_mbutton`.

- `HDPoint2D GetMposition(int *button) const`
  `HDPoint2D GetMposition(void) const`
  Returning the mouse position and the pressed button without waiting for a mouse click, see the reference manual entry of `get_mposition`.

- `HCircle DrawCircle(void) const`
  Waiting for the user to draw a circle in the window, see the reference manual entry of `draw_circle`.

- `HEllipse DrawEllipse(void) const`
  Waiting for the user to draw an ellipse in the window, see the reference manual entry of `draw_ellipse`.

- `HRectangle1 DrawRectangle1(void) const`
  Waiting for the user to draw a rectangle parallel to the coordinate axis in the window, see the reference manual entry of `draw_rectangle1`.

- `HRectangle2 DrawRectangle2(void) const`
  Waiting for the user to draw a rectangle with an arbitrary orientation and size in the window, see the reference manual entry of `draw_rectangle2`.
  ```

```
#include "HalconCpp.h"
using namespace Halcon;

main ()
{
  HImage  image("control_unit");     // Reading an image from a file
  HWindow w;                         // Opening an appropriate window
  image.Display(w);                  // Display the image
  w.SetLut("change2");               // Set a lookup table
  w.Click();                         // Waiting for a mouse click
  w.SetLut("default");               // Set the default lookup table
  w.SetPart(100,100,200,200);        // Set a part of the window
  image.Display(w);
  w.Click();
  // Adapting the part to the image again
  w.SetPart(0,0,bild.Height()-1,bild.Width()-1);
  image.Display(w);
  HRegionArray regs = image.Regiongrowing(1,1,4,100);
  w.SetDraw("margin");
  w.SetColored(6);
  regs.Display(w);
  w.Click();
  image.Display(w);
  w.SetShape("rectangle1");
  regs.Display(w);
}
```

Figure 12.10: Sample program for the use of the class `HWindow` .

Figure 12.10 shows the typical use of some member functions of the class `HWindow` and the different possibilities of displaying images and regions. The window is opened after reading the image from a file. This means, the window is scaled to the size of the image. The lookup table is changed afterwards, and the program waits for a mouse click in the window. A part of the image is zoomed now, and the program waits again for a mouse click in the window. By applying a region growing algorithm from the HALCON library (`Regiongrowing`) regions are generated and displayed in the window. Only the margin of the regions is displayed. It is displayed in 6 different colors in the window. The example ends with another way of displaying the shape of regions. The smallest rectangle parallel to the coordinate axes surrounding each region is displayed.

12.2.3.2 Other Handle Classes

Starting with version 6.1, HALCON/C++ (legacy) provides the so-called handle classes like `HFramegrabber`, `HBarCode`, or `HClassBoxMlp`.

Besides the default constructor, the classes typically provide additional constructors based on suitable operators as described in section 11.2.3 on page 76; e.g., the class `HBarCode` provides a constructor based on the operator `create_bar_code_model`.

All handle classes listed above provide the methods `SetHandle()` and `GetHandle()`, which allow to access the underlying handle; furthermore, the classes provide an operator that casts an instance of the class into the corresponding handle. These methods are typically used when combining procedural and object-oriented code; for examples please refer to section 11.5 on page 84.

The reference manual provides short overview pages for these classes, listing the operators that can be called via them.

12.3 Auxiliary Classes

In section 12.1.1 on page 87, you already got a glimpse of additional classes provided by HALCON/C++ (legacy): Instances of `HRegion` can be constructed from classes like `HDPoint2D` or `HRectangle1`. Currently, these classes are not documented in any of the manuals. We recommend to have a look at the header files in the directory `include/cpp`.

Please note that the header files in `include/cpp` include other classes, which do not appear in this manual. These classes are used by MVTec internally for testing purposes; they should not be used in an application.

Chapter 13

Creating Applications With HALCON/C++ (legacy)

The HALCON distribution contains examples for creating an application with HALCON/C++ (legacy). The following sections show

- the relevant directories and files (section 13.1)
- the relevant environment variables (section 13.2)
- how to create an executable under Windows (section 13.3 on page 113)
- how to create an executable under Linux (section 13.4 on page 113)

13.1 Relevant Directories and Files

Here is an overview of the relevant directories and files (relative to %HALCONROOT%, Windows notation of paths):

`include\cpp\HalconCpp.h`:
include file; contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ (legacy) interface.

`bin\%HALCONARCH%\halcon.dll`,
`lib\%HALCONARCH%\halcon.lib`:
The HALCON library (Windows).

`bin\%HALCONARCH%\halconcpp10.dll`,
`lib\%HALCONARCH%\halconcpp10.lib`:
The HALCON/C++ (legacy) library (Windows).

`bin\%HALCONARCH%\halconxl.dll, halconcpp10xl.dll`,

`lib\%HALCONARCH%\halconxl.lib, halconcpp10xl.lib:`
The corresponding libraries of HALCON XL (Windows).

`lib/$HALCONARCH/libhalcon.so:`
The HALCON library (Linux).

`lib/$HALCONARCH/libhalconcpp10.so:`
The HALCON/C++ (legacy) library (Linux).

`lib/$HALCONARCH/libhalconxl.so,libhalconcpp10xl.so:`
The corresponding libraries of HALCON XL (Linux).

`include\HProto.h:`
External function declarations.

`help\operators_*:`
Files necessary for online information.

`doc\pdf\:`
Various manuals (in subdirectories).

13.2 Relevant Environment Variables

In the following, we briefly describe the relevant environment variables; see the Installation Guide, section A.2 on page 64, for more information, especially about how to set these variables. Note, that under Windows, all necessary variables are automatically set during the installation.

While a HALCON program is running, it accesses several files internally. To tell HALCON where to look for these files, the environment variable `HALCONROOT` has to be set. `HALCONROOT` points to the HALCON home directory. `HALCONROOT` is also used in the sample makefile.

The variable `HALCONARCH` describes the platform HALCON is used on. Please refer to section 1.1 on page 13 for more information.

The variable `HALCONEXAMPLES` indicates where the provided examples are installed.

If user-defined packages are used, the environment variable `HALCONEXTENSIONS` has to be set. HALCON will look for possible extensions and their corresponding help files in the directories given in `HALCONEXTENSIONS`.

Two things are important in connection with the example programs: The default directory for the HALCON operator `read_image` to look for images is `\images`. If the images reside in different directories, the appropriate path must be set in `read_image` or the default image directory must be changed, using `set_system("image_dir","...")`. This is also possible with the environment variable `HALCONIMAGES`. It has to be set before starting the program.

The second remark concerns the output terminal under Linux. In the example programs, no host name is passed to `open_window`. Therefore, the window is opened on the machine that is specified in the environment variable `DISPLAY`. If output on a different terminal is desired, this can be done either directly in `OpenWindow(...,"hostname",...)` or by specifying a host name in `DISPLAY`.

In order to link and run applications under Linux, you have to include the HALCON library path `$HALCONROOT/lib/$HALCONARCH` in the system variable `LD_LIBRARY_PATH`.

13.3 Creating an Executable Under Windows

Your own C++ programs that use HALCON operators must include the file `HalconCpp.h`, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ (legacy) interface. Do this by adding the command

```
#include "HalconCpp.h"
```

near the top of your C++ file. In order to create an application you must link the library `halconcpp10.lib/.dll` to your program.

Please assure that the stacksize is sufficient. Some sophisticated image processing problems require up to 1 MB stacksize, so make sure to set the settings of your compiler accordingly (See your compiler manual for additional information on this topic).

HALCON XL applications: If you want to use HALCON XL, you have to link the libraries `halconxl.lib/.dll` and `halconcp10pxl.lib/.dll` instead of `halcon.lib/.dll` and `halconcpp10.lib/.dll` in your project.

13.4 Creating an Executable Under Linux

Your own C++ programs that use HALCON operators must include the file `HalconCpp.h`, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ (legacy) interface. Do this by adding the command

```
#include "HalconCpp.h"
```

near the top of your C++ file. Using this syntax, the compiler looks for `HalconCpp.h` in the current directory only. Alternatively you can tell the compiler where to find the file, giving it the `-I<pathname>` command line flag to denote the include file directory.

To create an application, you have to link two libraries to your program: The library `libhalconcpp10.so` contains the various components of the HALCON/C++ (legacy) interface. `libhalcon.so` is the HALCON library.

HALCON XL applications: If you want to use HALCON, you have to link the libraries `libhalconcpp10xl.so` and `libhalconxl.so` instead.

As a basic example: To compile your own C++ (legacy) application `example.cpp` using the GNU C++ compiler, the following call can be used:

```
g++ -I$HALCONROOT/include -I$HALCONROOT/include/cpp \
  -L$HALCONROOT/lib/$HALCONARCH -lhalconcpp10 -lhalcon -o example example.cpp
```

Chapter 14

Typical Image Processing Problems

This chapter shows the power the HALCON system offers to find solutions for image processing problems. Some typical problems are introduced together with sample solutions.

14.1 Thresholding an Image

Some of the most common sequences of HALCON operators may look like the following one:

```
HByteImage   Image("file_xyz");
HRegion      Threshold        = Image.Threshold(0,120);
HRegionArray ConnectedRegions = Threshold.Connection();
HRegionArray ResultingRegions =
               ConnectedRegions.SelectShape("area","and",10,100000);
```

This short program performs the following:

- All pixels are selected with gray values between the range 0 and 120.
- A connected component analysis is performed.
- Only regions with a size of at least 10 pixel are selected. This step can be considered as a step to remove some of the noise from the image.

14.2 Edge Detection

For the detection of edges the following sequence of HALCON/C++ (legacy) operators can be applied:

```
HByteImage Image("file_xyz");
HByteImage Sobel = Image.SobelAmp("sum_abs",3);
HRegion    Max   = Sobel.Threshold(30,255);
HRegion    Edges = Max.Skeleton();
```

A brief explanation:

- Before applying the sobel operator it might be useful first to apply a low-pass filter to the image in order to suppress noise.
- Besides the sobel operator you can also use filters like `EdgesImage`, `PrewittAmp`, `RobinsonAmp`, `KirschAmp`, `Roberts`, `BandpassImage`, or `Laplace`.
- The threshold (in our case 30) must be selected appropriately depending on data.
- The resulting regions are thinned by a `Skeleton` operator. This leads to regions with a pixel width of 1.

14.3 Dynamic Threshold

Another way to detect edges is e.g. the following sequence:

```
HByteImage Image("file_xyz");
HByteImage Mean      = Image.MeanImage(11,11);
HRegion    Threshold = Image.DynThreshold(Mean,5,"light");
```

Again some remarks:

- The size of the filter mask (in our case 11×11) is correlated with the size of the objects which have to be found in the image. In fact, the sizes are proportional.
- The dynamic threshold selects the pixels with a positive gray value difference of more than 5 (brighter) than the local environment (mask 11×11).

14.4 Texture Transformation

Texture transformation is useful in order to obtain specific frequency bands in an image. Thus, a texture filter detects specific structures in an image. In the following case this structure depends on the chosen filter; 16 are available for the operator `TextureLaws`.

```
HByteImage Image("file_xyz");
HByteImage TT   = Image.TextureLaws(Image,"ee",2,5);
HByteImage Mean = TT.MeanImage(71,71);
HRegion    Reg  = Mean.Threshold(30,255);
```

- The mean filter `MeanImage` is applied with a large mask size in order to smooth the "frequency" image.
- You can also apply several texture transformations and combine the results by using the operators `AddImage` and `MultImage`.

14.5 Eliminating Small Objects

The following morphological operator eliminates small objects and smoothes the contours of regions.

```
            ...
segmentation(Image,&Seg);
HCircle Circle(100,100,3.5);
HRegionArray Res = Seg.Opening(Circle);
```

- The term `segmentation()` is an arbitrary segmentation operator that results in an array of regions (`Seg`).
- The size of the mask (in this case the radius is 3.5) determines the size of the resulting objects.
- You can choose an arbitrary mask shape.

14.6 Selecting Oriented Objects

Another application of morphological operators is the selection of objects having a certain orientation:

```
          ...
segmentation(Image,&Seg);
HRectangle2 Rect(100,100,0.5,21,2);
HRegionArray Res = Seg.Opening(Rect);
```

- Again, `segmentation()` leads to an array of regions (`Seg`).
- The width and height of the rectangle determine the minimum size of the resulting regions.
- The orientation of the rectangle determines the orientation of the regions.
- Lines with the same orientation as `Rect` are kept.

14.7 Smoothing Contours

The last example in this user's manual deals again with morphological operators. Often the margins of contours have to be smoothed for further processing, e.g. fitting lines to a contour. Or small holes inside a region have to be filled:

```
          ...
segmentation(Image,&Seg);
HCircle Circle(100,100,3.5);
HRegionArray Res = Seg.Closing(Circle);
```

- Again, `segmentation()` leads to an array of regions (`Seg`).
- For smoothing the contour a circle mask is recommended.
- The size of the mask determines how much the contour is smoothed.

Part IV

Programming With HALCON/.NET

Chapter 15

Introducing HALCON/.NET

This chapter introduces you to HALCON/.NET. Chapter 16 on page 123 shows how to use it to create .NET applications, chapter 17 on page 143 contains additional information.

What is HALCON/.NET?

HALCON/.NET is HALCON's interface to .NET programming languages, e.g., C# or Visual Basic .NET. It provides you with a set of .NET classes and controls.

Why use HALCON/.NET and not HALCON/COM or HALCON/C++?

HALCON/.NET is a native .NET assembly, whereas HALCON/COM is used in .NET via so-called wrappers. This means that HALCON/.NET applications are faster than their HALCON/COM counterparts.

HALCON/C++ is meant for standard, i.e., unmanaged C++ applications. If your application needs both managed and unmanaged code, you can combine HALCON/C++ and HALCON/.NET.

Being the newest HALCON interface, HALCON/.NET provides you with state-of-the-art technology, e.g., an improved IntelliSense support in Visual Studio.

Platform Independency

HALCON/.NET is highly platform-independent: It is written in C# but can be used in any .NET language. Like .NET in general, it can be used under Windows and Linux, on 32-bit and 64-bit systems.

What's more, you can not only use it on all these platforms, but you can run an application created on one of them on the other ones without needing to recompile. This is possible because applications written in .NET languages are stored in a platform-independent intermediate language, which is then compiled by the so-called common language runtime into platform-specific code.

HDevEngine/.NET

By combining HALCON/.NET and HDevEngine/.NET, you can execute HDevelop programs and procedures from a .NET application. For more information, please refer to part VII on page 209.

HALCON/.NET XL and HDevEngine/.NET XL

In fact, two sets of assemblies are provided: HALCON/.NET and HDevEngine/.NET are based on HALCON, while HALCON/.NET XL and HDevEngine/.NET XL are based on HALCON XL, i.e., they use the XL versions of the HALCON library and of HDevEngine, respectively.

Chapter 16

Creating Applications With HALCON/.NET

This chapter shows you how to create applications with HALCON/.NET. The examples are given in C#, using Visual Studio .NET under Windows as development environment.

If programming constructs or activities differ in Visual Basic .NET or managed C++, this is noted at the first occurrence. How to create applications under Linux using Mono is described in section 17.3 on page 150.

The provided online help is listed in section 16.4.1 on page 129.

This chapter describes how to

- add HALCON/.NET to an application (section 16.2 on page 126)
- add and customize `HWindowControl` for visualization (section 16.3 on page 128)
- use HALCON/.NET classes to call HALCON operators (section 16.4 on page 129)
- work with tuples (section 16.5 on page 135)
- visualize images and results (section 16.6 on page 140)
- perform error handling (section 16.7 on page 141)
- deploy an application (section 16.8 on page 142)
- use a newer release of HALCON/.NET (section 16.9 on page 142)

Many of the code examples stem from the example `Matching`, which is provided in C# (`%HALCONEXAMPLES%\c#`), Visual Basic .NET (`%HALCONEXAMPLES%\vb.net`), and managed C++ (`%HALCONEXAMPLES%\cpp.net`). An overview of the provided example applications can be found in section 17.2 on page 148.

But before explaining how to create applications, we must take a brief look under the hood of .NET: at the dependency of applications on the .NET Framework.

16.1 .NET Framework, Development Environments, and Example Directory Structure

Chapter 15 on page 121 emphasized the platform-independency of .NET applications. However, applications are not completely independent: They depend on the version of the .NET Framework they have been created with, i.e., the underlying SDK, development environment, etc.

16.1.1 HALCON/.NET and .NET Framework Versions

Table 16.1 shows which version of Visual Studio is based on which version of the .NET Framework.

Visual Studio .NET 2002	→	.NET Framework 1.0
Visual Studio .NET 2003	→	.NET Framework 1.1
Visual Studio 2005	→	.NET Framework 2.0
Visual Studio 2008	→	.NET Framework 3.5
Visual Studio 2010	→	.NET Framework 4.0

Table 16.1: Versions of the .NET Framework and of development environments.

.NET Framework 1.1 is only an updated version of .NET Framework 1.0, whereas .NET Framework 2.0 added many new features, e.g., the support of managed C++ and 64-bit applications.

Consequently, the HALCON/.NET assembly is provided in three variants (with identical functionality):

- based on .NET Framework 1.0: in the directory `%HALCONROOT%\bin\dotnet10`
- based on .NET Framework 2.0: in the directory `%HALCONROOT%\bin\dotnet20`
- based on .NET Framework 3.5: in the directory `%HALCONROOT%\bin\dotnet35`

Newer versions of the .NET Framework provide backwards compatibility, e.g., .NET Framework 4.0 can use assemblies from 3.5. Mono at the time of writing implements most features of .NET Framework 3.5.

16.1.2 Example Directory Structure

Furthermore, the example applications (see section 17.2 on page 148 for an overview) are provided in a modular directory structure:

- ▷ `source`**:** contains shared source files
- ▷ `vs.net`**:** contains the project files for Visual Studio .NET 2002 and 2003
- ▷ `vs2005`**:** contains the project files for Visual Studio 2005 and Visual Studio 2008
- ▷ `vs2008`**:** contains the project files for Visual Studio 2008

- ▷ `makefiles`: contains makefiles for compiling the applications from the command line, in particular using Mono (see section 17.3 on page 150 for more information)

Thus, to open an example in Visual Studio .NET 2002 or 2003, you open the corresponding project file in the subdirectory `vs.net`. To open it in Visual Studio 2005 or Visual Studio 2008, you open the corresponding project file in the subdirectory `vs2005`. Note that only some examples have special support for Visual Studio 2008 and therefore have a subdirectory `vs2008`. If this is not the case, open the project file in `vs2005`.

Note that when opening a project in Visual Studio .NET 2003, the project will be upgraded automatically (with only minor changes to the project file). Table 16.2 lists more generally whether a project created with one version of Visual Studio can be opened with another.

created with \ open with	VS .NET 2002	VS .NET 2003	VS 2005	VS 2008
VS .NET 2002	×	×*)	×**)	×**)
VS .NET 2003	–	×	×**)	×**)
VS 2005	–	–	×	×*)
VS 2008	–	–	–	×

(*) minor upgrade (automatic)

(**) major upgrade (automatic)

Table 16.2: Compatibility of applications.

Please note that the provided examples reference the HALCON/.NET assembly using a local path. Therefore, when you copy an example to another location, the assembly will not be found, which is signalled in the Solution Explorer by a broken reference. In such a case, delete the reference and add the correct one as described in section 16.2.2.

If you are copying examples to locations other than on a local disk, please note that you must adapt the .NET Framework Configuration as described in section 17.5.1 on page 153, otherwise you get a warning upon loading the project and a run-time error upon executing it.

16.2 Adding HALCON/.NET to an Application

You add HALCON/.NET to an application with the following steps: For the first application:

- customize Visual Studio's toolbox (section 16.2.1)

For each application:

- add a reference to HALCON/.NET (section 16.2.2) and
- specify the namespace (section 16.2.3)

16.2.1 Customizing Visual Studio's Toolbox

In fact, the HALCON/.NET assembly provides not only a class library but also one control: `HWindowControl`, which contains a HALCON graphics window for visualizing images and results.

You can add this control to Visual Studio's toolbox by performing the following steps (note that the exact menu names are slightly different in different versions of Visual Studio!):

- Right-click on the toolbox and select `Customize Toolbox`. This will open a dialog displaying all available .NET Framework components in a tab.
- Click on `Browse`, navigate to the directory `%HALCONROOT%\bin\dotnet10` (Visual Studio .NET 2002 and 2003) or `%HALCONROOT%\bin\dotnet20` (Visual Studio 2005, Visual Studio 2008) and select `halcondotnet.dll`.
- Then, the icon of `HWindowControl` appears in the toolbox (compare figure 16.1).

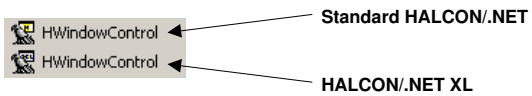


Figure 16.1: Adding `HWindowControl` to the toolbox.

HALCON XL applications: When developing an application with HALCON XL, you must select `halcondotnetxl.dll` instead of `halcondotnet.dll`. In the toolbox, the control appears with the same name but with a different icon (see figure 16.1). You can add both HALCON versions to the toolbox, but only one of them to an application.

16.2.2 Adding a Reference to HALCON/.NET

In many applications you will use at least one instance of `HWindowControl` to visualize results. By adding the control to the form (as described in section 16.3 on page 128), you automatically create a reference to the assembly `halcondotnet.dll`.

If you do not want to use `HWindowControl`, you add a reference as follows:

- Right-click `References` in the Solution Explorer and select `Add Reference`.

- Click on Browse, navigate to the subdirectory %HALCONROOT%\bin\dotnet10 (Visual Studio .NET 2002 and 2003) or %HALCONROOT%\bin\dotnet20 (Visual Studio 2005, Visual Studio 2008) and select the assembly halcondotnet.dll.

HALCON XL applications: When developing an application with HALCON XL, you must select halcondotnetxl.dll instead of halcondotnet.dll. If you already added a reference to the HALCON version, simply delete that reference and add one to halcondotnetxl.dll.

16.2.3 Specifying the Namespace

To be able to use the HALCON/.NET classes without prefixing them with their namespace, we recommend to specify this namespace at the beginning of each source file (see, e.g., the example MatchingForm.cs)) by adding the following line:

```
using HalconDotNet;
```

Visual Basic .NET applications: The corresponding Visual Basic .NET code is (see, e.g., MatchingForm.vb):

```
Imports HalconDotNet
```

C++ applications: The corresponding managed C++ code is (see, e.g., MatchingForm.h):

```
  using namespace HalconDotNet;
```

16.3 Adding and Customizing `HWindowControl` for the Visualization

In most application you want to visualize at least some results. Then, you start by adding `HWindowControl` to the form by double-clicking the corresponding icon in the toolbar (see figure 16.1 on page 126). An empty (black) window appears (see figure 16.2).

HALCON XL applications: If you already added the HALCON version of the control, but now want to use HALCON XL, simply delete the reference to `halcondotnet.dll` in the Solution Explorer and add a reference to `halcondotnetxl.dll` instead (also see section 16.2.2 on page 126).

If you want to visualize images (which is typically the case), you should **adapt the size of the window** to the size of the images to display, otherwise the display will be significantly slower because of the necessary interpolation. The window should have the same size as the image, or half its size, quarter its size, etc. To be more exact, it is not the image size that matters, but the size of the part of the image you want to display. But in most cases you will display the full image, then the two sizes are identical.

You can modify both the window size and the image part in the Property Window (see figure 16.2) by entering them in the properties `WindowSize` and `ImagePart`. Note that the part is specified with the values `X`, `Y`, `Width`, and `Height`, whereas the corresponding operator `SetPart` expects the four corner points.

Note that you can modify the displayed part in your application at any time, e.g., to display a zoomed part of the image. See section 16.6 on page 140 for more information about actually visualizing results.

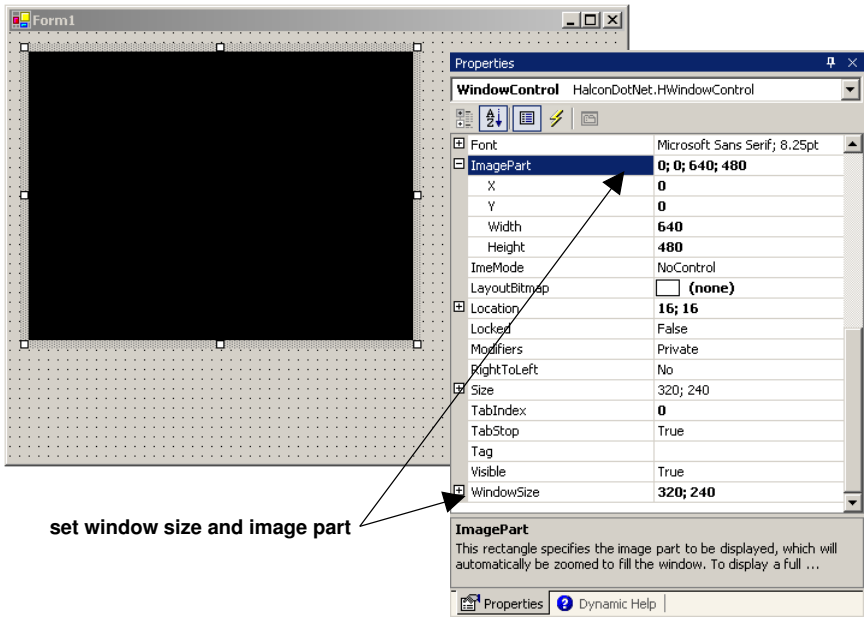


Figure 16.2: Adapting window size and image part of `HWindowControl`.

16.4 Using HALCON/.NET Classes

In HALCON/.NET, you call HALCON operators via instances of classes. The following code, e.g., grabs the first image of an image sequence and displays it in the graphics window of `HWindowControl`:

```
private HWindow                         Window;
private HFramegrabber                   Framegrabber;
private HImage                          Img;
```

```
Window = WindowControl.HalconWindow;
Framegrabber = new HFramegrabber("File", 1, 1, 0, 0, 0, 0, "default",
  -1, "default", -1, "default",
  "board/board.seq", "default", 1, -1);
Img = Framegrabber.GrabImage();
Img.DispObj(Window);
```

The operator `GrabImage` is called via an instance of `HFramegrabber`. As an experienced HALCON user you will perhaps have identified the constructor of `HFramegrabber` as a call to the operator `OpenFramegrabber`.

Below, we take a closer look at:

- how to call operators via HALCON/.NET's classes (section 16.4.2)
- construction, initialization, and destruction of class instances (section 16.4.3 on page 131)
- overloads of operator calls (section 16.4.4 on page 133)

But first, we give you an overview of the provided online help.

16.4.1 Online Help

The main source of information about HALCON/.NET operators and classes is the reference manual, which is available as HTML and PDF version (note that the latter is only provided in HDevelop syntax). Under Windows, you can open both versions via the Start Menu. Under Linux, open `table_of_contents.html` in the directory `$HALCONROOT/doc/html/reference/operators` , and `reference_hdevelop.pdf` in the directory `$HALCONROOT/doc/pdf/reference` , respectively. You can access them also via HDevelop's Help Browser.

The Reference Manual describes the functionality of each HALCON operator and its signatures, i.e., via which classes it can be called with which parameters. Furthermore, it gives an overview of the provided classes (which does not list all methods, however, only the HALCON operators).

Online help is also available in Visual Studio:

- When you type a dot (`.`) after the name of a class or class instance, the automatic context help (IntelliSense) lists all available methods.
- Similarly, when you type the name of a method, its signature(s) is (are) listed.

- For parameters of HALCON operators, a short description and the the so-called default value is shown. Note that HALCON operators do not have "real" default parameter values, i.e., you cannot leave out a parameter and let HALCON use a default value. Instead, the listed default value is a typical value chosen for the parameter.
- The Object Browser lists all HALCON/.NET classes with their methods, including a short description.

16.4.2 Calling HALCON Operators

Via which classes you can call a HALCON operator is listed in the reference manual. Figure 16.3 shows the corresponding part of the description of the operator `GrabImage`:

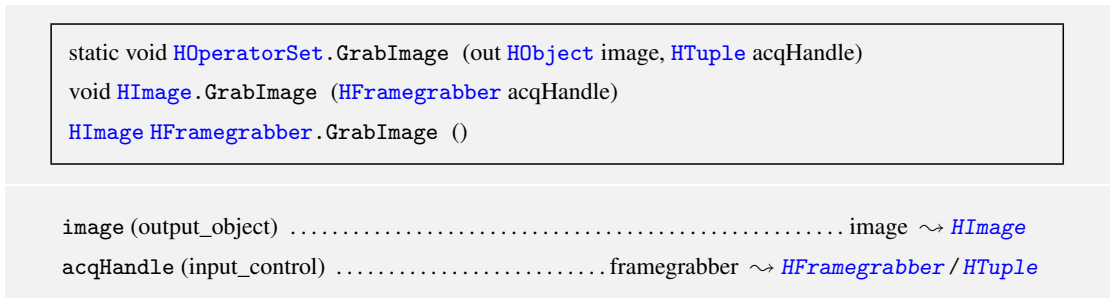

static void HOperatorSet.GrabImage (out HObject image, HTuple acqHandle)
void HImage.GrabImage (HFramegrabber acqHandle)
HImage HFramegrabber.GrabImage ()
image (output_object) ..... image ⇝ HImage
acqHandle (input_control) ..... framegrabber ⇝ HFramegrabber / HTuple

Figure 16.3: The head and parts of the parameter section of the reference manual entry for `GrabImage`.

As you can see, the operator can be called via three classes: `HOperatorSet`, `HImage`, and `HFramegrabber`. The first variant, via `HOperatorSet`, is mainly used for the export of HDevelop programs (see section 17.4 on page 152).

For normal applications, we recommend to call operators via the other classes, in the example `HImage` and `HFramegrabber` as in the following code example:

```
HImage                                Image1;
HImage                                Image4 = new HImage();
HFramegrabber Framegrabber =
  new HFramegrabber("File", 1, 1, 0, 0, 0, 0, "default", -1,
  "default", -1, "default", "board/board.seq", "default", -1, -1);

Image1 = Framegrabber.GrabImage();
HImage                                Image3 = null;
```

Note that in the call via `HFramegrabber` the grabbed image is the return value of the method, whereas the call via `HImage` has no return value and the calling class instance is modified instead. Usually, calling class instances are not modified by an operator call - with the exception of "constructor-like" operator calls as in the example above.

Some operators like `CountSeconds` are available as class methods, i.e., you can call them directly via the class and do not need an instance:

```
double            S1, S2;

S1 = HSystem.CountSeconds();
```

In the reference manual, these operator calls start with the keyword `static`:

static void HOperatorSet.CountSeconds (out HTuple seconds)

static double HSystem.CountSeconds ()

Figure 16.4: The head of the reference manual entry for `CountSeconds`.

16.4.3 From Declaration to Finalization

During the lifecycle of an object, i.e., from declaration to finalization, different amounts of memory are allocated and released.

The following **declaration** just declares a variable of the class `HImage` that does not yet refer to any object:

```
HImage                                  Image1;
```

In this state, you cannot use the variable to call operators; depending on the programming language, you might not even be able to use it as an output parameter (e.g., in Visual Basic 2005). However, you can assign image objects to the variable, e.g., from the return value of an operator:

```
Image1 = Framegrabber.GrabImage();
```

You can also **initialize** a variable when declaring it:

```
HImage                                  Image2 = Framegrabber.GrabImage();
HImage                                  Image3 = null;
```

Note that you can check the initialization state of a class instance with the method `IsInitialized`.

16.4.3.1 Constructors

In contrast, the following declaration calls the “empty” constructor of the class `HImage`, which creates an unititialized class instance:

```
HImage                                  Image4 = new HImage();
```

This class instance can be used to call "constructor-like" operators like `GrabImage`, which initializes it with a grabbed image:

```
Image4.GrabImage(Framegrabber);
```

Besides the empty constructor, most HALCON/.NET classes provide one or more constructors that initialize the created object based on HALCON operators. For example, `HImage` provides a constructor based on the operator `ReadImage`:

```
HImage                                  Image5 = new HImage("fuse");
```

You can check which constructors are provided via the online help:

- The reference manual pages for the classes don't list the constructors themselves but the operators they are based on. The constructor then has the same signature as the operator (minus the output parameter that corresponds to the class, of course).
- The online help in Visual Studio lists the constructors but not the operators they are based on.

16.4.3.2 Finalizers

The main idea behind memory management in .NET is that the programmer does not worry about it and lets the garbage collector delete all objects that are not used anymore. HALCON/.NET fully complies to this philosophy by providing corresponding finalizers for all classes so that even unmanaged resources, e.g., a connection to an image acquisition device, are deleted correctly and automatically.

For most classes, the finalizer automatically calls suitable operators like `CloseFramegrabber` to free resources. Which operator is called is listed in the reference manual page of a class (see, e.g., the entry for `HFramegrabber`). This operator cannot be called via the class, as can be seen in the corresponding reference manual entry:

static void HOperatorSet.CloseFramegrabber (HTuple acqHandle)

Figure 16.5: The head of the reference manual entry for `CloseFramegrabber`.

You do not even need to call such an operator if you, e.g., want to re-open the connection with different parameters, because this is done automatically.

Please **don't call `Close` or `Clear` operators via `HOperatorSet` when using the normal classes** like `HFramegrabber`.

16.4.3.3 Garbage Collection

As remarked above, the .NET philosophy is to let the garbage collector remove unused objects. However, because the garbage collector deletes unused objects only from time to time, the used memory increases in the meantime. Even more important is that, to the garbage collector, HALCON's iconic variables (images, regions, ...) seem to be rather "small", because they only contain a reference to the (in many cases rather large) iconic objects in the database. Thus, the garbage collector may not free such variables even if they are not used anymore.

Therefore, you might need to force the removal of (unused) objects. There are two ways to do this:

- Call the garbage collector manually. In the example `Matching`, this is done after each processing run in the timer event:

  ```
  private void Timer_Tick(object sender, System.EventArgs e)
  {
    Action();
    GC.Collect();
    GC.WaitForPendingFinalizers();
  }
  ```

  C++ applications: The code for calling the Garbage Collector in a managed C++ application is

  ```
  GC::Collect();
  GC::WaitForPendingFinalizers();
  ```

- Dispose of individual objects manually by calling the method `Dispose`:

  ```
  HImage          Image = new HImage("fuse");
    ...
  Image.Dispose();
  ```

Besides reducing memory consumption, another reason to manually dispose of objects is to free resources, e.g., close a connection to an image acquisition device or a serial interface.

Please note that HALCON operators always create a new object instance for output parameters and return values (but not in the "constructor-like" operator calls that modify the calling instance). If the variable was already initialized, its old content (and the memory allocated for it) still exists until the garbage collector removes it. If you want to remove it manually, you must call `Dispose` *before* assigning an object to it.

16.4.4 Operator Overloads

Some classes overload standard operators like + (addition) to call HALCON operators. The following line, e.g., adds two images by internally calling `AddImage`:

```
Image5 = Image1 + Image2;
```

Please note that **operator overloads are not available in Visual Basic .NET!**

The following tables list the currently available operator overloads.

Operator overloads for `HImage`

- (unary)	inverts an image
+ (image)	adds two images
- (image)	subtracts image2 from image1
∗ (image)	multiplies two images
+ (scalar)	adds a constant gray value offset
- (scalar)	subtracts a constant gray value offset
∗ (scalar)	scales an image by the specified factor
/ (scalar)	scales an image by the specified divisor
>= (image)	segments an image using dynamic threshold
<= (image)	segments an image using dynamic threshold
>= (scalar)	segments an image using constant threshold
<= (scalar)	segments an image using constant threshold
& (region)	reduces the domain of an image

Operator overloads for `HRegion`

& (region)	returns the intersection of regions
| (region)	returns the union of regions
/ (region)	returns the difference of regions
! (unary)	returns the complement of the region (may be infinite)
& (image)	returns the intersection of the region and the image domain
+ (region)	returns the Minkowski addition of regions
- (region)	returns the Minkowski subtraction of regions
+ (scalar)	dilates the region by the specified radius
- (scalar)	erodes the region by the specified radius
+ (point)	translates the region
∗ (scalar)	zooms the region
- (unary)	transposes the region

Operator overloads for `HFunction1D`

+ (scalar)	adds a constant offset to the function's Y values
- (scalar)	subtracts a constant offset from the function's Y values
- (unary)	negates the Y values of the function
∗ (scalar)	scales the function's Y values
/ (scalar)	scales the function's Y values
∗ (function)	composes two functions (not a point-wise multiplication)
! (unary)	calculates the inverse of the function

16.5 Working with Tuples

A strength of HALCON is that most operators automatically work with multiple input values (tuple values). For example, you can call the operator `AreaCenter` with a single or with multiple input regions; the operator automatically returns the area and center coordinates of all passed regions. Analogously, if you call `GenRectangle1` with multiple values for the rectangle coordinates, it creates multiple regions.

The following sections provide more detailed information about

- how to find out whether an operator can be called in tuple mode (section 16.5.1)
- tuples of iconic objects (section 16.5.2)
- tuple of control values (section 16.5.3 on page 137)

16.5.1 Calling HALCON Operators with Single or Multiple Values

You can check whether an operator also works with tuples in the reference manual. Below, e.g., we show the relevant parts of the operators `AreaCenter` and `GenRectangle1`.

As you see, the iconic classes like `HRegion` automatically handle multiple values; whether such a parameter accepts / returns multiple values is not visible from the signature but only in the parameter section: Here, an appended `(-array)` (in the example: `HRegion(-array)`) signals that the parameter can contain a single or multiple values.


```
static void HOperatorSet.AreaCenter (HObject regions, out HTuple area, out HTuple row,
    out HTuple column)
HTuple HRegion.AreaCenter (out HTuple row, out HTuple column)
int HRegion.AreaCenter (out double row, out double column)
```

`regions` (input_object) ..... region(-array) ⇝ *HRegion*
`area` (output_control) ..... integer(-array) ⇝ *HTuple (int*
`row` (output_control) ..... point.y(-array) ⇝ *HTuple (double)*
`column` (output_control) ..... point.x(-array) ⇝ *HTuple (double)*

```
static void HOperatorSet.GenRectangle1 (out HObject rectangle, HTuple row1, HTuple column1,
    HTuple row2, HTuple column2)
public HRegion (HTuple row1, HTuple column1, HTuple row2, HTuple column2)
public HRegion (double row1, double column1, double row2, double column2)
void HRegion.GenRectangle1 (HTuple row1, HTuple column1, HTuple row2, HTuple column2)
void HRegion.GenRectangle1 (double row1, double column1, double row2, double column2)
```

```
rectangle (output_object) ..... region(-array) ⇝ HRegion
row1 (input_control) ..... rectangle.origin.y(-array) ⇝ HTuple (double
column1 (input_control) ..... rectangle.origin.x(-array) ⇝ HTuple (double
row2 (input_control) ..... rectangle.corner.y(-array) ⇝ HTuple (double
column2 (input_control) ..... rectangle.corner.x(-array) ⇝ HTuple (double
```

In contrast, control parameters show by their data type whether they contain a single or multiple values: In the first case, they use basic data types like `double`, in the second case the HALCON/.NET class `HTuple`. Thus, you can call `GenRectangle1` via `HRegion` in two ways, either by passing `doubles` or `HTuples` (here using the constructor form):

```
HRegion SingleRegion = new HRegion(10.0, 10.0, 50.0, 50.0);
HRegion MultipleRegions = new HRegion(new HTuple(20.0, 30.0), new HTuple(20.0, 30.0),
                                      new HTuple(60.0, 70.0), new HTuple(60.0, 70.0));
```

Similarly, `AreaCenter` can be called in two ways:

```
double Area, Row, Column;
HTuple Areas, Rows, Columns;

Area = SingleRegion.AreaCenter(out Row, out Column);
Areas = MultipleRegions.AreaCenter(out Rows, out Columns);
```

Below, we provide additional information about iconic tuples (section 16.5.2) and control tuples (section 16.5.3).

16.5.2 Iconic Tuples

The iconic classes `HImage`, `HRegion`, and `HXLD` can contain single of multiple objects. To process all elements of a tuple you first **query the number of elements** with with the operator `CountObj`

```
int NumRegions = MultipleRegions.CountObj();
```

and then **access elements** either with the HALCON operator `SelectObj` or (when using C#) with the operator `[]`:

```
for (int i=1; i<=NumRegions; i++)
{
  HRegion Region = MultipleRegions[i];
  ...
}
```

Note that in iconic tuples **element indices start with 1!**

You can **create or extend iconic tuples** with the HALCON operator `ConcatObj`:

```
HRegion ThreeRegions = SingleRegion.ConcatObj(MultipleRegions);
```

16.5.3 Control Tuples and the Class `HTuple`

For control tuples, HALCON/.NET provides the class `HTuple`. Instances of `HTuple` can contain elements of the types `double`, `int`, and `string`. They can also contain a mixture of element types.

The following sections describe

- how to access tuple elements (section 16.5.3.1)
- how to create tuples (section 16.5.3.2)
- the automatic cast methods and how to resolve ambiguities caused by the casts (section 16.5.3.3)
- HALCON operators for processing tuples (section 16.5.3.4 on page 140)
- proved overloads for arithmetic operations (section 16.5.3.5 on page 140)

16.5.3.1 Accessing Tuple Elements

To process all elements of a tuple, you first query its length via the property `Length`:

```
int TupleLength = Areas.Length;
```

You can access tuple elements with the operator `[]`:

```
for (int i=0; i<TupleLength; i++)
{
  double Element = Areas[i];
  ...
}
```

Note that you get an exception if you try to read a non-existing tuple element or if you try to assign an element to a variable with a different type without cast.

16.5.3.2 Creating Tuples

The class `HTuple` provides many different constructors (see the Visual Studio's Object Browser for a list). The following line creates an `int` tuple with a single value:

```
HTuple Tuple1 = new HTuple(1);
```

In contrast, the following line creates a `double` tuple:

```
HTuple Tuple2 = new HTuple(1.0);
```

You can also pass multiple values to a constructor. Note that when mixing `double` and `int` values as in the following line, a `double` tuple is created:

```
HTuple Tuple3 = new HTuple(1.0, 2);
```

In contrast, when the list of values also contains a `string`, a **mixed type** tuple is created, in which the second value is stored as an `int`:

```
HTuple Tuple4 = new HTuple(1.0, 2, "s");
```

The **type of a tuple or of a tuple element** can be queried via its property `Type`:

```
HTupleType TupleType = Tuple4.Type;
HTupleType TupleElementType = Tuple4[1].Type;
```

You can **concatenate tuples** very simply by passing them in a constructor:

```
HTuple Tuple5 = new HTuple(Tuple2, Tuple3);
```

You can also append elements to a tuple by writing into a non-existing element:

```
Tuple3[2] = 3;
```

16.5.3.3 Casts, Ambiguities, Unexpected Results

The class `HTuple` provides many implicit cast methods so that you can intuitively use the basic data types in most places. For example, the line

```
double Element = Areas[i];
```

automatically casts the element, which is in fact an instance of the class `HTupleElement`, into a `double`.

Similarly, basic types are automatically casted into instances of `HTuple`. The drawback of the casts is that the compiler often cannot decide whether you want to use the simple or the tuple version of an operator and issues a corresponding error. For example, if you used the following line, the values can either be casted from `int` to `double` or to `HTuple`:

```
// HRegion SingleRegion = new HRegion(10, 10, 50, 50);
```

You can **resolve the ambiguity** very simply by appending `.0` to the first parameter:

```
HRegion SingleRegion = new HRegion(10.0, 10.0, 50.0, 50.0);
```

The example Matching contains two other cases of ambiguities, both arising because basic-type and HTuple parameters are mixed in the same call. In the first, the ambiguity is solved by explicitly casting the double parameters into instances of HTuple:

```
private double                          Row, Column;
HTuple            RowCheck, ColumnCheck, AngleCheck, Score;
HHomMat2D         Matrix = new HHomMat2D();
Matrix.VectorAngleToRigid(new HTuple(Row), new HTuple(Column), new HTuple(0.0),
  RowCheck, ColumnCheck, AngleCheck);
```

In the second case, the instances of HTuple (which only contain single values) are explicitly casted into doubles by using the property D, which returns the value of the first element as a double (actually, it is a shortcut for tuple[0].D):

```
private double                          RectPhi, RectLength1, RectLength2;
HTuple            Rect1RowCheck, Rect1ColCheck;
Rectangle1.GenRectangle2(Rect1RowCheck.D, Rect1ColCheck.D,
  RectPhi + AngleCheck.D,
  RectLength1, RectLength2);
```

With similar properties, you can cast tuple elements into the other basic types. Note, however, that you get an exception if you try to cast an element into a "wrong" type.

In contrast to input parameters, output parameters are not automatically casted. Sometimes, this leads to unexpected results. In the following code, e.g., doubles are used for the output parameters and the return value in a call to AreaCenter with a tuple of regions:

```
HRegion MultipleRegions = new HRegion(new HTuple(20.0, 30.0), new HTuple(20.0, 30.0),
                                      new HTuple(60.0, 70.0), new HTuple(60.0, 70.0));
double Area, Row, Column;
HTuple Areas, Rows, Columns;

Area = MultipleRegions.AreaCenter(out Row, out Column);
```

Consequently, only the area and the center of the first region are returned. The same happens if you assign the return value to an HTuple, but still pass doubles for the output parameters:

```
Areas = MultipleRegions.AreaCenter(out Row, out Column);
```

In contrast, if you pass HTuples for the output parameters and assign the return value to a double, the operator returns the center coordinates of all regions but only the area of the first region:

```
Area = MultipleRegions.AreaCenter(out Rows, out Columns);
```

16.5.3.4 HALCON Operators for Processing Tuples

HALCON provides many operators for processing tuples. In the reference manual, these operators can be found in the chapter "Tuple". An overview of these operators is given in the HDevelop User's Guide in chapter 8 on page 337. Note that instead of the operator name, the name of the corresponding HDevelop function is used, which omits the `Tuple` and uses lowercase characters, e.g., `rad` instead of `TupleRad`.

16.5.3.5 Operator Overloads

For the basic arithmetic operations, HALCON/.NET provides operator overloads. For example, the operator + automatically calls the HALCON operator `TupleAdd`.

16.6 Visualization

In most applications you will use an instance of `HWindowControl` for the display of images of results. How to configure this control is described in section 16.3 on page 128. The actual display operators, however, do not use the control but the HALCON graphics window (class `HWindow`) encapsulated inside. You can access the graphics window via the property `HalconWindow` of `HWindowControl`:

```
private HWindow                       Window;

private void Form1_Load(object sender, System.EventArgs e)
{
  Window = WindowControl.HalconWindow;
}
```

In the code above, the variable for the instance of `HWindow` was declared globally and initialized in the event `Load` of the form. If you (also) want to run your application under Linux, you currently cannot use this event (see the restrictions of Mono listed in section 17.3.1 on page 150). Instead, you can perform the initialization in the event `HInitWindow` of `HWindowControl`:

```
private void WindowControl_HInitWindow(object sender, System.EventArgs e)
```

You can configure the display parameters like pen color or line width with the operators in the reference manual chapter "Graphics ▷ Parameters":

```
Window.SetDraw("margin");
Window.SetLineWidth(3);
```

Images and other iconic objects are displayed with the operator `DispObj`, which can be called via the object to display with the window as parameter or vice versa:

```
Img.DispObj(Window);
```

More display operators, e.g., to display lines or circles, can be found in the reference manual chapter "Graphics ▷ Output".

Instead of (or in addition to) using `HWindowControl`, you can also open a HALCON graphics windows directly with the operator `OpenWindow`:

```
HWindow         ZoomWindow = new HWindow(0, 0, width, height, 0, "visible", "");
```

In the code above, the window was opened "free-floating" on the display. You can also open it within another GUI element by passing its handle in the parameter `fatherWindow`.

Before displaying anything in the graphics window, you should set the image part to display with the operator `SetPart`. In the example code below, the opened window is used to display a zoomed part of the image:

```
ZoomWindow.SetPart(row1, col1, row1+height-1, col1+width-1);
```

More information about visualization in general can be found in the Solution Guide I, chapter 19 on page 303. Note that in this manual, the HDevelop version of the display operators is used, i.e., with the prefix `dev_`, e.g., `dev_open_window` instead of `OpenWindow`.

16.7 Error Handling

The .NET programming languages each offer a mechanism for error handling. In C# and managed C++, you use `try...catch` blocks. Within this standard mechanism, HALCON/.NET offers its special exceptions:

- `HOperatorException` is raised when an error occurs within a HALCON operator
- `HTupleAccessException` is raised when an error occurs upon accessing a HALCON tuple

The following code shows how to catch the error that occurs when the operator `ReadImage` is called with a wrong image file name. Then, a message box is shown that displays the error number in the caption and the HALCON error message:

```
HImage Image;

try
{
  Image = new HImage("unknown");
}
catch   (HOperatorException     exception)
{
  MessageBox.Show(exception.Message, "HALCON error # " + exception.GetErrorNumber());
}
```

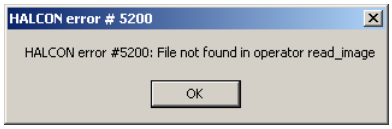


Figure 16.6: Catching an HALCON operator error and displaying its message.

16.8 Deploying an Application

By default, .NET applications use local assemblies. For HALCON/.NET applications, this means that the HALCON/.NET assembly `halcondotnet.dll` is automatically copied to the directory of the application's executable (e.g., `bin\Release`). To deploy an application on another computer, you therefore simply copy the content of this directory. Because of .NET's platform independency, this computer can also run under a different operating system than the development computer.

Of course, the .NET Framework and HALCON must be installed on the destination computer as well, and the environment variables `PATH` and `HALCONARCH` must be set correctly (see the Installation Guide, section A.2 on page 64).

Note that you can also install the HALCON/.NET assembly in the so-called global assembly cache. Then, it is not necessary to copy it with each application. See the .NET Framework documentation for details about this method.

16.9 Using a Newer HALCON/.NET Release

Please note that applications that use HALCON/.NET have local copies of the corresponding assemblies. After installing a newer release of HALCON, these applications would therefore still use their old HALCON assemblies. In order to benefit from the changes in the HALCON/.NET interface as well, you must either replace the assemblies manually or re-compile the projects.

If you replace the assemblies manually, you must furthermore map the application's expected assembly version to the new version. For this, copy the file `bin\dotnet10\app.config` or `bin\dotnet20\app.config` (identical files) into the directory of the application and rename it to `<application_name>.exe.config`.

Another application of the configuration file is the case that a Visual Studio project references an assembly based on HALCON that expects another maintenance release of HALCON. In this case, you must add `app.config` to the project and re-compile it.

Chapter 17

Additional Information

This chapter provides additional information for developing applications with HALCON/.NET:

- Section 17.1 describes the so-called HALCON Codelets, a set of classes and example projects that let you use part of HDevelop's functionality for interactive application development.
- Section 17.2 on page 148 gives an overview of the available example applications.
- Section 17.3 on page 150 explains how to use HALCON/.NET applications under Linux using Mono.
- Section 17.4 on page 152 shows how to use HDevelop programs or procedures in your .NET application.
- Section 17.5 on page 153 contains miscellaneous information.

17.1 HALCON Codelets

With HALCON Codelets, you can use (part of) HDevelop's functionality for interactive application development within a programmed application. HALCON Codelets are provided in form of classes and example projects. Currently, they are provided only for HALCON/.NET (C#, Visual Studio 2005/2008). They reside in the directory `%HALCONEXAMPLES%\codelets`. An HTML API reference can be found via the start menu (or under `doc\html\reference\codelets\index.html`).

You can use HALCON Codelets in different ways:

- by copying complete projects or solutions and adapting them to your needs,
- by using / referencing parts the classes,
- by looking at the source code and learning how to implement HDevelop's functionality.

Please note, however, that **the API of HALCON Codelets is not fixed yet**, thus, coming versions might not be source-code compatible.

Currently, the following functionality is provided:

- `base\`
  - `ViewROI`

    This class library provides basic visualization functionality of HDevelop like the interactive control of the graphics window, interactive ROI handling, etc. How to use the individual classes is demonstrated in the application examples listed below.

- `assistants\`
  - `Calibration`

    This class library provides the functionality of HDevelop's Calibration Assistant (see the HDevelop User's Guide, section 7.1 on page 225). How to use the classes is demonstrated in one of the application examples listed below.
  - `Matching`

    This class library provides the functionality of HDevelop's Matching Assistant (see the HDevelop User's Guide, section 7.3 on page 252). How to use the classes is demonstrated in one of the application examples listed below.
  - `Measure`

    This class library provides the functionality of HDevelop's Measure Assistant (see the HDevelop User's Guide, section 7.4 on page 293). How to use the classes is demonstrated in one of the application examples listed below.

- `applications\`
  - `GraphicsWindow`

    This application uses the visualization classes to re-implement HDevelop's graphics window, including interactive zooming and scaling image and window size (see figure 17.1).
  - `GraphicsStack`

    This application uses the visualization classes to re-implement HDevelop's graphics stack, i.e., the visualization of iconic objects on top of each other (see figure 17.2).
  - `InteractiveROI`

    This application uses the visualization classes to re-implement HDevelop's interactive ROI creation (see figure 17.3 on page 146).
  - `SmartWindow1`

    This application uses the visualization classes for a graphics window with interactive image zooming and moving that can be controlled via sliders (see figure 17.4 on page 146).
  - `SmartWindow2`

    This application uses the visualization classes for a graphics window with interactive image zooming and moving that can be controlled via the mouse (see figure 17.5 on page 147).
  - `Calibration`

    This application uses the visualization classes and the classes for the calibration assistant to implement an interactive calibration environment (see figure 17.6 on page 147).

– `Matching`

  This application uses the visualization classes and the classes for the matching assistant to implement an interactive matching environment (see figure 17.7 on page 148).

– `Measure`

  This application uses the visualization classes and the classes for the measure assistant to implement an interactive matching environment (see figure 17.8 on page 148).

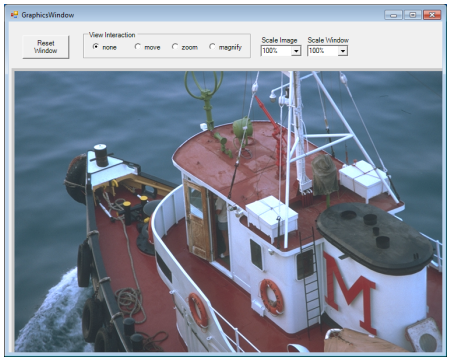


Figure 17.1: HALCON Codelets application using the re-implemented graphics window.

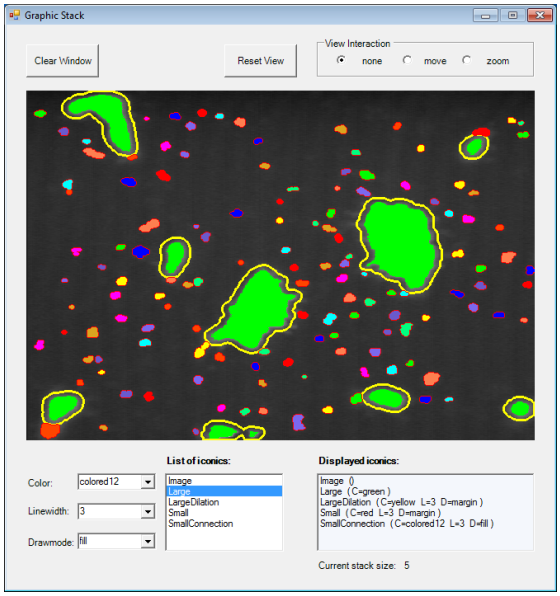


Figure 17.2: HALCON Codelets application demonstrating the graphics stack.

Figure 17.3: HALCON Codelets application for interactive ROI control.

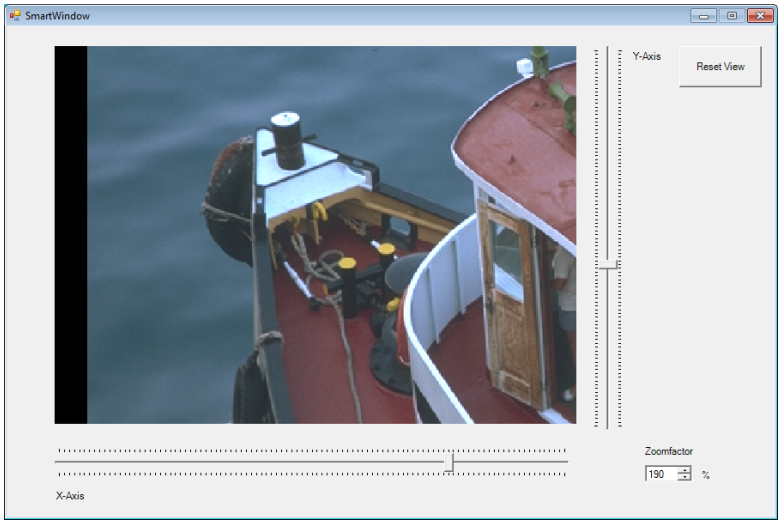


Figure 17.4: HALCON Codelets application for zooming and moving the image with sliders.

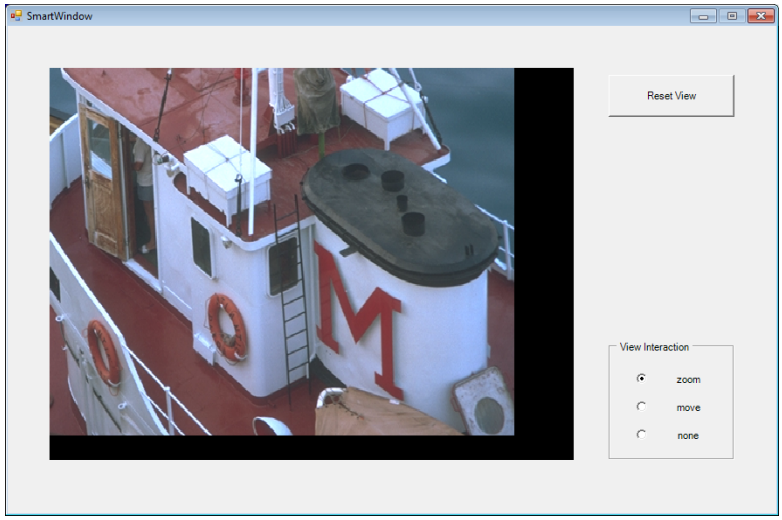


Figure 17.5: HALCON Codelets application for zooming and moving the image with the mouse.

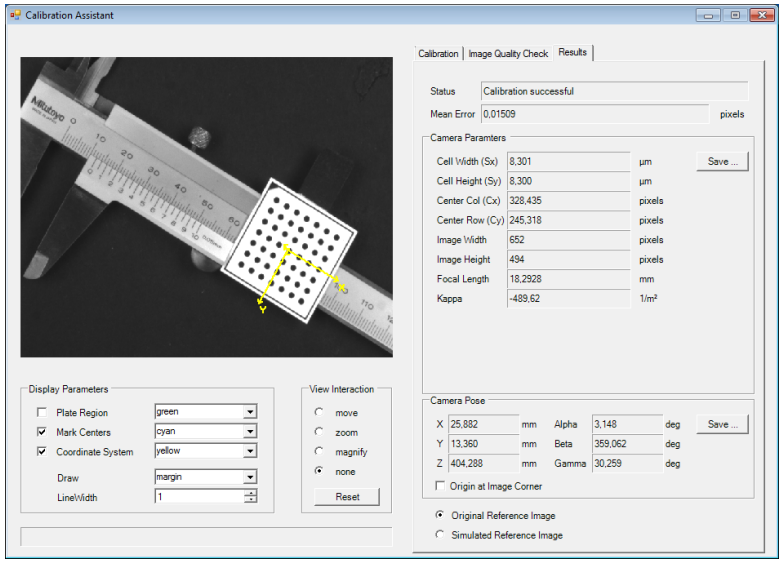


Figure 17.6: HALCON Codelets application for interactive calibration.

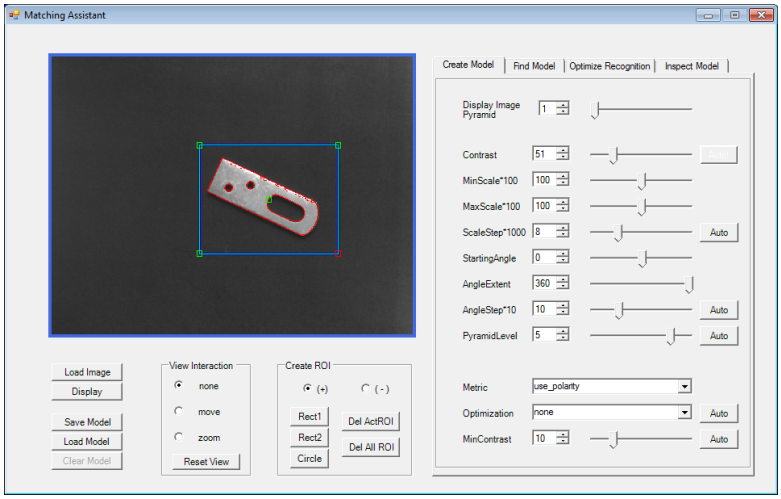


Figure 17.7: TODO: HALCON Codelets application for interactive matching.

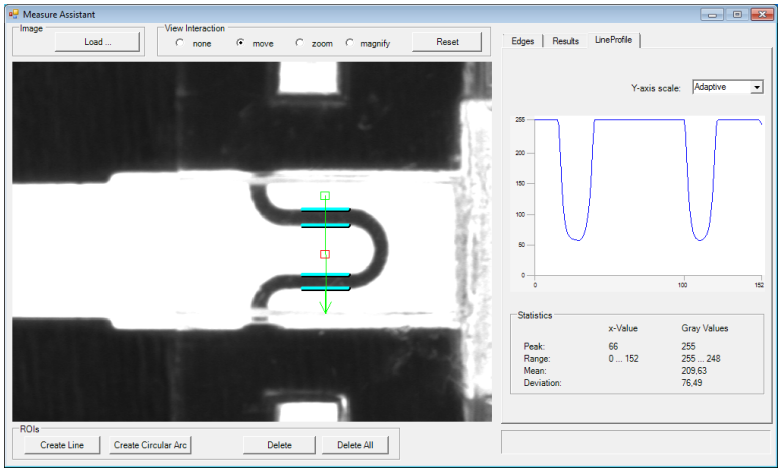


Figure 17.8: HALCON Codelets application for interactive 1D measuring.

17.2 Provided Examples

The following sections briefly describe the provided example applications for

- C# (section 17.2.1)
- Visual Basic .NET (section 17.2.2)
- (managed) C++ (section 17.2.3 on page 150)

All paths are relative to %HALCONEXAMPLES%.

17.2.1 C#

- c#\Matching (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Locate an IC on a board and measure pin distances using shape-based matching (HShapeModel) and 1D measuring (HMeasure)

- c#\MatchingWPF (Visual Studio 2008)

  Matching example to demonstrate the use of HALCON in a WPF application using Visual Studio 2008 or higher.

- c#\MultiThreading (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Use HALCON/.NET with multiple threads for image acquisition, processing (2D data code reading, HDataCode2D), and display

- hdevengine\c#\ExecProgram (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Execute an HDevelop program for fin detection using HDevEngine

- hdevengine\c#\ExecExtProc (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Execute an external HDevelop procedure for fin detection using HDevEngine

- hdevengine\c#\ExecProcedures (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Execute local and external HDevelop procedures for fin detection using HDevEngine

- hdevengine\c#\ErrorHandling (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Handle HDevEngine exceptions

- hdevengine\c#\MultiThreading (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Executing an HDevelop procedure in parallel by two threads using HDevEngine/.NET

- hdevengine\c#\MultiThreadingTwoWindows (Visual Studio .NET 2002/2003, Visual Studio 2005/2008, Mono)

  Executing different HDevelop procedures in parallel by two threads using HDevEngine/.NET

17.2.2 Visual Basic .NET

- vb.net\Matching (Visual Studio .NET 2002/2003, Visual Studio 2005/2008)

  Locate an IC on a board and measure pin distances using shape-based matching (HShapeModel) and 1D measuring (HMeasure)

- `hdevengine\vb.net\ExecProgram` (Visual Studio .NET 2002/2003, Visual Studio 2005/2008)

  Execute an HDevelop program for fin detection using HDevEngine

- `hdevengine\vb.net\ExecExtProc` (Visual Studio .NET 2002/2003, Visual Studio 2005/2008)

  Execute an external HDevelop procedure for fin detection using HDevEngine

- `hdevengine\vb.net\ExecProcedures` (Visual Studio .NET 2002/2003, Visual Studio 2005/2008)

  Execute local and external HDevelop procedures for fin detection using HDevEngine

- `hdevengine\vb.net\ErrorHandling` (Visual Studio .NET 2002/2003, Visual Studio 2005/2008)

  Handle HDevEngine exceptions

17.2.3 C++

- `cpp.net\Matching` (Visual Studio 2005/2008)

  Locate an IC on a board and measure pin distances using shape-based matching (`HShapeModel`) and 1D measuring (`HMeasure`)

  Please note that the files of this example are not located in subdirectories as described in section 16.1.2 on page 124 but all reside directly in the example directory.

- `cpp.net\Interoperate` (Visual Studio 2005 or higher)

  Demonstrate the use of a HALCON/C++ DLL from within a HALCON/.NET application using Visual Studio 2005 or higher.

17.3 HALCON/.NET Applications under Linux Using Mono

Chapter 16 on page 123 describes in detail how to develop HALCON/.NET applications in general. The following sections contain additional information for the case that you want to create applications under Linux using Mono:

- restrictions (section 17.3.1)
- how to deploy applications created under Windows (section 17.3.2)
- how to compile an application with Mono (section 17.3.3)
- other GUI libraries (section 17.3.4 on page 152)

17.3.1 Restrictions

Please note the following restrictions when developing or using HALCON/.NET applications via Mono:

- Mono supports Windows Forms but does not claim to implement the full functionality (yet). This has to be kept in mind when developing applications under Windows and compiling or deploying them under Linux.
- `HWindowControl` is not yet initialized in the event `Load` of a form, due to a different initialization order of X Window widgets. Please place initialization and similar code in the event handler of `HWindowControl`'s event `HInitWindow` (see e.g. the example `Matching`):

```
private HWindow                         Window;
private HFramegrabber                   Framegrabber;
private HImage                          Img;

private void WindowControl_HInitWindow(object sender, System.EventArgs e)
{
  Window = WindowControl.HalconWindow;
  Framegrabber = new HFramegrabber("File", 1, 1, 0, 0, 0, 0, "default",
    -1, "default", -1, "default",
    "board/board.seq", "default", 1, -1);
  Img = Framegrabber.GrabImage();
  Img.DispObj(Window);
}
```

- When using HALCON under Mono, only ASCII characters in the range 0-127 may be passed in string parameter between application and HALCON library, unless it is known in advance that the data within the HALCON library actually represents valid UTF-8. The reason is that Mono only supports marshalling to/from UTF-8 when calling into native libraries. For example, the call

```
HOperatorSet.TupleChr(128, out t)
```

  will fail with an exception on Mono, as the one-byte string containing only the value of 128 is not valid UTF-8 and cannot be marshalled into the output string.

17.3.2 Deploying HALCON/.NET Applications Created under Windows

Because of HALCON/.NET's platform independency, you can copy an application created under Windows to a Linux computer and simply start it there - provided that Mono and HALCON are installed on the destination computer (see section 16.8 on page 142 for more information).

17.3.3 Compiling HALCON/.NET Applications with Mono

Most of the HALCON/.NET examples provide a set of makefiles in the subdirectory `makefiles` to let you compile them under Linux (see section 17.2 on page 148 for a list of the examples that support Linux). To start the compilation, simply type

```
gmake
```

The executable is placed in the subdirectory `makefiles/bin`.

```
<configuration>
  <dllmap dll="halcon"
          target="/opt/halcon/lib/x86-linux2.4-gcc33/libhalcon.so"/>
</configuration>
```

Figure 17.9: Example for a configuration file with HALCON being installed in the directory `/opt/halcon`.

HALCON XL applications: To create a HALCON/.NET XL application, type

```
gmake XL=1
```

In some cases, Mono may not find the native HALCON library `libhalcon.so`, which should be resolved via the environment variable `LD_LIBRARY_PATH` and issue a corresponding error. You can create configuration files for the HALCON/.NET (and HDevEngine/.NET) assembly, which explicitly specify the path to the HALCON library (see figure 17.9 for an example), by calling

```
gmake config
```

If you want to create a configuration file for only one of the assemblies, use the make commands `config_halcon` and `config_engine`.

17.3.4 Using Other GUI Libraries

In principle, you could also use other GUI libraries instead of Windows Forms, e.g., Gtk#. Note, however, that `HWindowControl` is a Windows Forms element and thus can no longer be used. Instead, you can open HALCON graphics windows directly with the operator `OpenWindow`. If you want to place a graphics window inside another element, pass the element's native window handle in the parameter `fatherWindow`.

Please note that HALCON/.NET has not been tested with other GUI libraries.

17.4 Using HDevelop Programs

You can use HDevelop programs or procedures in two ways in your .NET application:

- by executing them directly via HDevEngine (see part VII on page 209 for detailed information) or
- by exporting them into C# or Visual Basic .NET code via the menu item `File` ▷ `Export` (see the HDevelop User's Guide, section 6.2.1.13 on page 60) and integrating the code in your application.

The latter method is described in this section.

17.4.1 Using the Template Application

In most cases you will manually integrate the exported code into your application. To quickly test the exported code, you can integrate it into the so-called template project (available for C# and Visual Basic .NET) in the subdirectory `HDevelopTemplate` (or `HDevelopTemplateWPF`, depending on your preferred GUI platform) as follows:

- Move or copy the exported source code file into subdirectory `source` of the template application.
- Open the solution file, right-click in the Solution Explorer, and select the menu item `Add Existing Item`. Navigate to the source code file, but don't click `Open` but on the arrow on the right side of this button and select `Link File` (see figure 17.10).

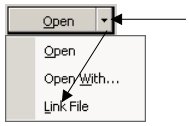


Figure 17.10: Linking existing items to an application.

- When you run the application, the form depicted in figure 17.11 appears. Click `Run` to start the exported HDevelop program.
- If you did not add the exported code correctly, the error message depicted in figure 17.12 appears. In Visual Basic .NET, different error messages appear.

17.4.2 Combining the Exported Code with the HALCON/.NET Classes

The exported code does not use the classes like `HImage` described in the previous chapter. Instead, all operators are called via the special class `HOperatorSet`. Iconic parameters are passed via the class `HObject` (which is the base class of `HImage`, `HRegion`, and `HXLD`), control parameters via the class `HTuple`.

You can combine the exported code easily with "normal" HALCON/.NET code because iconic classes provide constructors that initialize them with instances of `HObject`. Furthermore, iconic classes can be passed to methods that expect an `HObject`.

17.5 Miscellaneous

17.5.1 .NET Framework Security Configuration

If you want to develop .NET application (independent on the used HALCON interface) in other locations than on a local disk, you must configure the .NET security policy to allow executing code from your desired project location. Otherwise, you get a warning upon creating or loading the project that the location is not trusted and a run-time error upon executing it.

You can configure the .NET security policy in two ways:

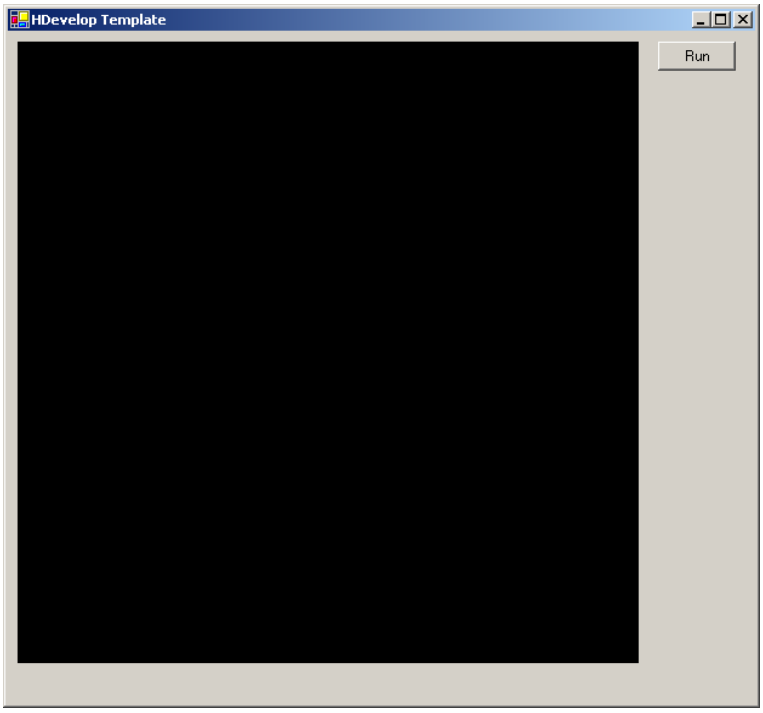


Figure 17.11: The template form for exported code.

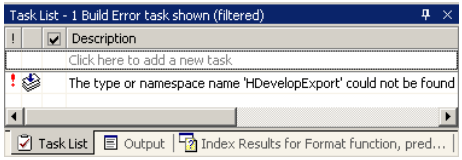

Task List - 1 Build Error task shown (filtered)
Description
Click here to add a new task
The type or namespace name 'HDevelopExport' could not be found
Task List
Output
Index Results for Format function, pred...

Figure 17.12: Error message upon running a template without exported code.

- with the command line tool `caspol`
- with the "Microsoft .NET Framework Configuration":
  - Open the Control Panel and select the `Administrative Tools`.
  - Select `.NET Framework Configuration` (if there is more than one entry, select the .NET Framework version corresponding to your current development environment, see table 16.1 on page 124 for an overview).
  - In the appearing dialog, select `My Computer` ▷ `Runtime Security Policy` ▷ `Machine` ▷ `Code Groups` ▷ `All Code` ▷ `LocalIntranet_Zone` in the left column and then select `Edit Code Group Properties` in the right column.
  - Another dialog appears; here, select the tab `Permission Set` and set the permissions to `FullTrust`.

Note that you need administrator privileges to change the .NET security policy.

Further note that to create .NET applications in Visual Studio, you must be a member of the group `Debugger User`.

17.5.2 HALCON/.NET and Remote Access

For performance reasons, HALCON/.NET suppresses unmanaged code security when making calls into the native HALCON library. Should your machine vision application run in an environment which allows remote access, you might wish to explicitly check permissions for code calling into your application or library.

Part V

Programming With HALCON/COM

Chapter 18

Introduction

This chapter provides a short overview of the main aspects of component-based software development and shows how this can be achieved with Microsoft COM (Component Object Model). It is not intended to discuss all aspects of COM in detail in this manual; please refer to the corresponding literature.

18.1 The Microsoft Component Object Model (COM)

Component-based software engineering has been discussed intensively in the past years. Concrete standards evolving from this discussion include DCE, CORBA, Microsoft COM, and lately the Microsoft Common Language Runtime , which is part of the .NET framework. The main features of components are:

1. Reusability at *binary* level independent of the used language
2. Object orientation
3. Robust versioning
4. Location Transparency

Microsoft COM is the base for many commonly used software technologies, e.g., ActiveX, OLE and DirectX. There are numerous tools for developing COM components, e.g., Visual Basic and Visual C++ (and their .NET versions), or Borland Delphi.

18.1.1 COM and .NET

As already mentioned, Microsoft provides a second approach to component-based programming with the Common Language Runtime of the .NET framework. The two approaches are independent, i.e., a COM component is not related to a .NET component and vice versa. However, the two can communicate with each other; furthermore, you can create COM components within Visual Studio .NET just as within Visual Studio.

18.1.2 A Quick Look at Some Programming Aspects

The following sections take a closer look at some programming aspects of COM:

- interfaces (section 18.1.2.1)
- objects, methods, data members (section 18.1.2.2)
- inheritance and polymorphism (section 18.1.2.3)
- early and late binding (section 18.1.2.4)

18.1.2.1 Interfaces

An important aspect of COM is the usage of component interfaces. Compared to the C++ terminology, an interface corresponds to the *declaration* of a class, thus showing its functionality and hiding the (internal) implementation details. This encapsulation allows to use a COM component efficiently, without the need to know anything about its implementation.

In contrast to a C++ class, a COM component can have *multiple* interfaces. This is useful, e.g., for the versioning: Once defined, an interface stays exactly the way it is. Newer versions of the component then define enhanced or extended functionality by new interfaces, while allowing existing software to remain unchanged, because it can still use the older interfaces. Furthermore, you can partition a component's functionality into several well-defined portions via multiple interfaces.

There are a couple of standard COM interfaces every component has by default, e.g., `IUnknown` and `IDispatch`. They are not described in this manual; please refer to appropriate literature.

18.1.2.2 Objects, Methods and Data Members

Just as with C++ classes there are interfaces in COM and those interfaces are made up from some methods. Several objects of a class correspond to several instances of a component, each with its own internal state. However, there are some differences with data members, as their handling within COM depends on the tool the component is used by. COM follows a concept of *properties*, which are special methods allowing tools like Visual Basic to treat them just like data members. With C++ they still are only methods, thus there is no way to modify and retrieve data members directly. From this point of view COM class data members can be compared with C++ private class members.

18.1.2.3 Inheritance and Polymorphism

As COM is a binary standard, inheritance must also take place at binary level which makes the process slightly uncomfortable. Without going into detail one can say that the only thing of interest here is that there are two methods of reusing existent components: *containment* and *aggregation*. Both techniques are commonly used by C++ programmers as well: Containment corresponds to C++ classes instantiated as a member object in other classes, whereas aggregation roughly corresponds to inheritance.

The main difference between containment and aggregation is the way the interface(s) of the contained/aggregated component(s) are handled: The methods and properties of a *contained* component

are hidden to the outside so that only the containing component can use them. Any method that should be visible from outside has to be re-defined in the outer component. In contrast to this, the interface(s) of an *aggregated* component are merged with the interfaces of the aggregating one, thus automatically making their methods visible to the outside.

The object-oriented feature of *polymorphism* is also achieved through interfaces: Different COM classes exposing the same interface can be understood as showing polymorphic behavior, as they act differently responding to the same methods.

18.1.2.4 Early and Late Binding

Binding is the process of resolving the call addresses of a component's exposed methods. This can be done at compilation time (*early binding*) or at runtime (*late binding*). Thus, when using a component you can take a specification of the contained methods and integrate it directly into the application. Therefore, the specification must be available in a format that fits the used programming language (e.g., when using C++ as client language one would typically include the header files containing the method declarations).

Alternatively, you can let the methods be bound at runtime; in this case, no language-dependent information is needed for compiling and the calling mechanism is totally different. Without going into details we want to point out that runtime-bound methods calls are *slower* than their early-bound counterparts. The HALCON/COM interface supports both early and late binding so that special needs of different applications can be satisfied.

18.2 HALCON and COM

With the HALCON/COM interface you can use the full functionality of the HALCON library within COM components (and therefore also ActiveX controls) developed, e.g., using Microsoft Visual Basic or Borland Delphi. In fact, there are two HALCON/COM interfaces, one to HALCON and one to HALCON XL, which is optimized for large images. How to use the latter is described in section 20.4 on page 178.

Chapter 19

The HALCON/COM Interface

Let's have a closer look at the HALCON/COM interface. This language interface (provided in form of the DLL `halconx.dll`) contains the full functionality of HALCON partitioned into several *classes*. Each class has one or more *interfaces*, which are built up from *methods* and *properties*. The HALCON/COM interface uses inheritance and thus contains derived classes and also an abstract base class. Since COM is not meant to supply a standardized inheritance mechanism, HALCON/COM makes extensive use of interfaces to simulate inheritance (we will discuss this topic in more detail afterwards).

Naming Conventions:

- Classes are capitalized and begin with an "*H*". They always end with an upper-case "*X*"; for example: `HFramegrabberX`.
- Interfaces are also capitalized and end with "*X*", but begin with an "*I*"; for example: `IHObjectX`.
- Methods, properties and parameters are capitalized; for example: `GrabImage`, `FileName`.

Since COM is only available for the Windows operating systems family, all file paths and environment variables in this manual are printed in the Windows convention, e.g.,

```
%HALCONROOT%\examples\vb6\Matching
```

to denote a subdirectory containing an example project within the HALCON base directory referenced by the environment variable `HALCONROOT`.

19.1 More about Classes

Classes are the essential items to deal with when writing HALCON/COM applications. There are quite a lot of them and there are different types of classes, thus we will have a closer look on how classes are used and what attributes they have. The classes of the HALCON/COM interface are partly related in a way which could be described as inheritance. Therefore, it is important to get an impression of how inheritance is achieved within HALCON/COM and how to use it.

19.1.1 Different Types of Classes

There are two major categories of classes:

1. classes instantiating objects that have an internal state and
2. classes instantiating objects with no internal state.

The first category is used to implement special data structures (like images, files, image acquisition devices, etc.) and the operators belonging to this data, whereas the second category is only used to group operators belonging together. If several objects of a class belonging to the first category are instantiated, they are all different from the HALCON point of view, whereas the second category does not have this quality. For example, if we consider several objects instantiated from the image class `HImageX`, they all denote something different: they represent different HALCON images. In contrast, if we have an object of a class like `HSystemX` that represents the internal state of the HALCON kernel, it does not matter how many of those objects will be instantiated, because all of them denote the same (there is only one HALCON kernel to be represented). Those classes can be understood as *group classes*, denoting that they supply a bunch of methods that all have some semantic peculiarities in common.

In contrast to this, methods of the first category classes may share a common semantics, but work on different data. For example, if an object of the class `HImageX` is instantiated, its methods always work exactly on one specific HALCON image: the one that is represented by the object (to be precise an `HImageX` object may also represent an *array* of images). Different `HImageX` objects represent different images and therefore work on different data.

Besides the first two groups, we can categorize classes in another way well known in the object oriented world:

1. abstract classes and
2. non-abstract classes.

A class is called abstract, if it can not be instantiated. Thus, an abstract class must be the base class for other classes, if it should be of any use. The idea behind this concept is that abstract classes provide a semantic base for their derived classes without being concrete enough for instantiation. A look on real world terms reveals many analogous cases: there is, e.g., the class *animal* which can be seen as an abstract base class for classes like *fish*, *bird* and *horse*. Any existing being can not be only an animal, it is always either a fish, a bird or a horse (or whatever else). There is only one such abstract class in the HALCON/COM interface: `HObjectX`. It represents a HALCON iconic object, such as an image, a region, or an XLD. The derived classes (`HImageX`, `HRegionX` and so on) then specify the exact type of the HALCON iconic object (see also the class overview in figure 19.1).

19.1.2 Classes for Special Purposes

There are some HALCON/COM classes that have special jobs. Although they do fit into the above systematics, they are worth mentioning, because they have to be used in a specific way or show some specific semantics.

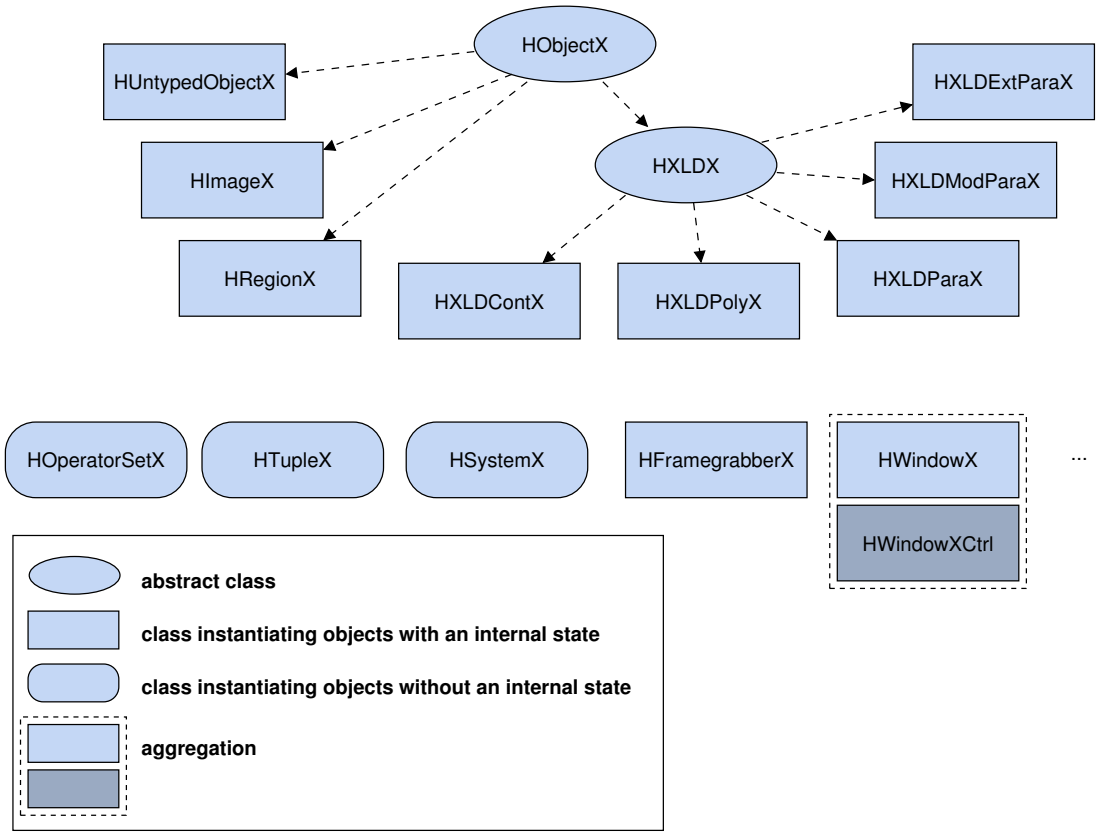


Figure 19.1: Main part of the HALCON/COM class hierarchy.

19.1.2.1 HWindowXCtrl

This class is a HALCON window in the form of an *ActiveX control*. Its advantage against the ordinary HALCON window (`HWindowX`) is the possibility to exist inside an *ActiveX container*. An ActiveX container is a part of a window which can contain GUI elements, such as buttons, sliders and so on. When developing complex image processing applications, it is often necessary to integrate all user interaction components (input and output) seamlessly into one surface. The HALCON window class `HWindowX` does not provide this flexibility, since it always appears as a top-level window. In order to behave like an ordinary `HWindowX` window, `HWindowXCtrl` uses the COM technique of *aggregation*. Thus, any newly created `HWindowXCtrl` automatically instantiates an `HWindowX` object which is bound to the control.

19.1.2.2 HOperatorSetX

This is basically a group class for all existing HALCON operators. `HOperatorSetX` is meant to provide access to a procedural way of HALCON programming. The reason for that is the fact that it is easier for some non-object-oriented tools like HDevelop to generate COM code automatically when using a

procedural technique. The specificity about HOperatorSetX is that all its methods require instances of HUntypedObjectX (see below) for all iconic input and output parameters. Furthermore, all control parameters (input and output) are of the type VARIANT (see also section 19.5 on page 169).

Hand-written COM code should not use the HOperatorSetX/HUntypedObjectX concept, since it weakens the otherwise strong-typed object-oriented approach; it becomes relevant only in cases, where automatically generated code is involved.

19.1.2.3 HUntypedObjectX

The class HUntypedObjectX is derived from HObjectX just like HImageX, HRegionX and so on. Its purpose is to get an instantiable form of the abstract base class. The class does not have any members, as it just consists of a polymorphic data type without any special meaning. As it is this weak-typed, it can not be used together with the strong-typed methods of the other classes, except by using the method Cast() which allows arbitrary type conversions between all classes derived from HObjectX (explained later on). HUntypedObjectX is meant to be a generic data type used by the special class HOperatorSetX.

19.1.2.4 The Method Cast()

All classes derived from HObjectX supply the method Cast() which is used for type conversions between the concerned classes. This method breaks up the well-defined data type scheme evolving from the class hierarchy, so it should not be used except when there is no other possibility! By using the method Cast(), an image object can be turned into a region, an XLD can become an HUntypedObjectX object and so on. The reason for that is, as mentioned above, the need to convert back and forth to the HUntypedObjectX objects used by the HOperatorSetX methods. For example, if an automatically generated code fraction produces an object variable of type HUntypedObjectX which shall be used as an image in some handwritten code, it can be forced to become an HImageX object. Of course, it must be assured that the variable really *does* contain an image (it is the programmer's task to take care for that).

The following short Visual Basic example reads an image via HOperatorSetX and then casts it into the class HImageX. Note that in order to apply the method Cast(), the variable Image must be a "living" COM object, thus it is declared as New HImageX. See section 19.7 on page 170 for more information about using HALCON/COM within Visual Basic.

```
Dim Op As New HOperatorSetX
Dim Untyped As HUntypedObjectX
Dim Image As New HImageX

Call Op.ReadImage(Untyped, "monkey")
Call Image.Cast(Untyped)
```

19.2 Object Construction and Destruction

19.2.1 Construction

A HALCON/COM object can be in different states. It can be *instantiated* and it can be *initialized*. An instantiated object does not necessarily need to be initialized, but an initialized object is always instantiated. Instantiation means using an appropriate technique to produce a "living" COM object (this technique differs according to what client language is used). Initializing means to give the object a well-defined internal state.

There is another state an object can have: neither instantiated nor initialized. Since not being instantiated means not existing, what exactly does this condition mean? The answer depends somewhat on the client language used, but is rather easy to understand, if we realize that COM object variables actually are *references* to an existing (or not existing) object. Thus, if such a variable is declared, there is not necessarily already an object created it refers to. As we like to mix up the terms "reference to an object" and "object" in this manual, we may speak of an uninstantiated object in that case. For example, if an `HImageX` object is created (not only the referring variable is declared), it is usable in terms of COM (since it is instantiated), but it does *not* yet contain any HALCON image. To be a valid HALCON/COM object, it still must be initialized. This can be done in two different ways:

- The object can initialize itself or
- the object can be initialized by another object's method.

In the first case, a so-called *constructor* is executed. The term "constructor" is somewhat misleading here, since it has a slightly different meaning than, e.g., a C++ constructor. In C++ terms, a constructor is a special method (always named exactly as the class) which performs the object construction *automatically* without the need to be called explicitly. In the HALCON/COM, case a constructor is an ordinary method which initializes the object's internal state and must be called explicitly.

For that reason, a HALCON/COM class can have many (differently named) constructors. One of the constructors of the class `HImageX`, e.g., is `ReadImage`, which initializes the object by reading an image file from the hard disk. Another way to initialize an object is to get it as result after calling another object's method. For example, an uninitialized `HImageX` object becomes initialized when it is returned from a call to `MeanImage` (which does a convolution on an image and produces another image).

Note that the mechanism is indeed slightly more complicated and again depends on the client language. In fact, an object variable needs *not* refer to a living COM object, when being used as a return value of a method call. Even more, if it *does*, the referred object gets destroyed before the new object is assigned to the variable.

Actually, there is yet another way to initialize a HALCON/COM object: by using the method `Cast()` mentioned before. This method takes another object of a related class, i.e., derived from `HObjectX`, as parameter, which in turn has to be initialized. Then, the object the calling method belongs to gets initialized with the internal state of the other object. Because no copying or duplication takes place, the other object gets *uninitialized*.

Note that not all HALCON/COM objects can have this initialized state! An object can only be initialized, if it *has* an internal state. Thus, all the group classes described in section 19.1.1 on page 164 have no constructor methods.

19.2.2 Destruction

We have seen that creating a valid HALCON/COM object is a two-step process: First, the COM object needs to be instantiated, then it must be initialized. This implies also a two-step destruction process: To destruct an object it must be uninitialized before being destroyed (which is the opposite of being instantiated). The latter is done by COM and the client environment, the first must be performed by some *automatic destruction process*. To pick up the `HImageX` example again, the automatic destructor must free the image data using the HALCON memory management. The automatic destructors of classes like `HShapeModelX` or `HFramegrabberX` internally apply operators like `ClearShapeModel` or `CloseFramegrabber`, respectively. These operators cannot be called via instances of the class (only via `HOperatorSetX`); the same holds for operators like `ClearAllShapeModels`. Instead of using these operators, you can destroy instances and then initialize anew.

Please note that you must not use operators like `ClearShapeModel`, `ClearAllShapeModels`, or `CloseFramegrabber` via `HOperatorSetX` together with instances of the corresponding handle classes (`HShapeModelX`, `HFramegrabberX`, etc.)!

19.3 Interfaces and Inheritance

As said before, COM classes are built from *interfaces* which in turn contain methods and properties. Each HALCON/COM class has got one default interface named according to the class. For example, the class `HImageX` contains the default interface `IHimageX` which provides all the relevant methods. Dealing with interfaces is strongly related to the client environment used, so we will not have a too close look at this topic now. For example, Visual Basic tries to completely hide the whole interface topic from the user; in that case, an interface and the related class are the same most of the time.

Actually, an interface behaves similar to a C++ pointer or reference to an object and that is exactly what Visual Basic tries to hide. As said before, interfaces are used for inheritance simulation within HALCON/COM. The way this works is simple: We have seen that `HObjectX` is an abstract (and thus not instantiable) class. On the other hand, the derived classes `HImageX`, `HRegionX`, etc. have to supply their own functionality *plus* the inherited `HObjectX` functionality. This is achieved with the help of interfaces: Currently there is *no* COM class named `HObjectX` (thus no `HObjectX` object can be initialized), only an interface named `IHObjectX`. This interface appears in all "derived" classes together with their default interfaces. `HImageX`, e.g., has two interfaces (in fact it has a hidden third one):

1. `IHImageX` (the default interface) and
2. `IHObjectX` (the inherited interface).

This allows to satisfy every method which expects a parameter `HObjectX` (actually it expects a reference to that class in form of the interface `IHObjectX`) with any derived class object, as such an object always has the interface `IHObjectX`, too. This corresponds to a certain object-oriented rule which allows an automatic cast from the derived class to the base class (not the other way).

How intuitive this feature can be used, again depends on the client language/tool: Visual Basic 5.0, for example, only regards the default interface an object supplies and treats that as if it were the class itself. That implies that only the methods contained in the default interface seem to belong to a class. To also use the "inherited" methods (contained in the `IHObjectX` interface), thus an explicit cast to the base class is necessary. This is a widely known Visual Basic weakness and may get improved by Microsoft in forthcoming versions.

19.4 Methods and Properties

There is not much to say about **methods**, since they can be used quite intuitively. The only interesting aspect here is the fact that different classes can have methods with the same name, but with a different parameter configuration. These methods perform the same action (as their identical names let expect), but "show a different point of view". For example, the operator `GrabImage` is part of the class `HImageX` as well as of the class `HFramegrabberX`. In the first case, the method is a constructor for an image object and takes an `HFramegrabberX` object as parameter (which denotes the image acquisition device from which to retrieve the data). In the second case, the method takes the `HImageX` object into which the image should be grabbed as parameter.

Properties are a special COM feature and can be treated like data members by tools like Visual Basic. There are two kinds of them: *put* and *get* properties. A put property allows the user to change the internal state of an object, whereas the get property only allows to read out the internal state. Usually (but not always), both types are present acting like an ordinary variable class member in C++. The properties in the HALCON/COM interface are just for convenience purposes, since they always map to an existing method. The class `HWindowX`, e.g, has quite a lot of properties: `Draw` sets or gets the current drawing mode, `Font` sets or gets the current font, and so on. All of these properties are mapped to their corresponding methods. Reading out the draw mode, e.g., results in a call to the operator `GetDraw`.

19.5 A Closer Look at Data Types

We have seen that a lot of the data types used within the HALCON/COM interface are actually the classes themselves. But there are also more basic, "everyday" types being used. A widely used data type in the COM world (and thus in Visual Basic) is the type `VARIANT`. All users of the HALCON/C++ interface will know the data type `HTuple` which is polymorphic (i.e., it can be one of several different "subtypes") and supplies array functionality (i.e., it can hold several data items at once). `VARIANT`s behave analogously and are the COM equivalent for `HTuples`. Exactly like an `HTuple` a `VARIANT` is able to hold data of different basic types plus the information what kind of data it contains. Also a combination of different or equal types is possible just like with `HTuples`.

The main difference is that a `VARIANT` is no class. This implies the complete absence of any methods. Thus, all the additional functionality of the very powerful class `HTuple` must be accessed in another way. For this reason, there is an class `HTupleX`, which groups methods for tuple operations like vector addition, string concatenation, and so on.

Another important and widely used COM data type is `BSTR`. This standard COM flavor of character strings is not directly compatible with standard C-like string implementations, mainly because it uses wide chars. This means, that auxiliary functions must be used to access or modify `BSTR`s when using C/C++. Again, this is no problem with Visual Basic, where it is the default string data type. Additionally, there are integral data types like `long` and `double` as well. They are used in situations where array- or multitype-parameters are not allowed or make no sense.

19.6 Error Handling

The HALCON/COM interface uses the standard COM error handling technique where every method call passes both a numerical and a textual representation of the error to the calling framework. It is then up to the caller to react to this information. Since low error numbers are reserved for COM, HALCON/COM uses a very high offset to its own error codes. To get the correct HALCON error code, this offset must be subtracted from the received code. The offset is a (read only) property of the class `HSystemX`. There are two offsets: one for the HALCON/COM *interface* and one for HALCON itself. Those properties are named:

- `HSystemX.ErrorBaseCOM` and
- `HSystemX.ErrorBaseHalcon`.

In order to get the correct HALCON error code, an `HSystemX` object must be instantiated (one is enough for the whole application anyway, since `HSystemX` objects have no "identity"). Then, the value of the respective property of `HSystemX` must be subtracted from the returned error code to get the correct HALCON error code. For an example how to deal with error codes see section 19.7.2.

Special information for error handling in Visual Basic can be found in section 19.7.2.

19.7 HALCON/COM and Visual Basic

So far, the important basics of the HALCON/COM interface have been explained. The following sections describe special aspects when using Visual Basic:

- object instantiation (section 19.7.1)
- error handling (section 19.7.2)

19.7.1 Object Instantiation

There are many different ways to instantiate COM objects in Visual Basic. We will discuss only one of them, because it has certain advantages over all the others. We have seen in the sections before that a distinction should be made between the instantiation and the initialization of objects. Even more important, we should also distinguish objects from object reference variables. An object reference variable is set up by its declaration with the keyword `Dim`:

```
Dim image1 As HImageX
```

This statement does *not* yet create a COM object, it just declares a variable able to reference an `HImageX` object. If we want to declare a reference variable and immediately create an object it refers to, we should write

```
Dim image1 As New HImageX
```

Now, a "new" HImageX object is created and the variable 'image1' refers it. Note that the declaration of variables is not obligatory with Visual Basic, but should be done anyway! Undeclared variables get declared automatically when referenced and that can lead to errors which are very hard to track down! It is a good idea to place the statement 'Option Explicit' on top of every Visual Basic module, because then variable declaration is forced.

We now have a valid COM object, to which the declared variable refers. To initialize this object, we could call a constructor method:

```
Dim image1 As New HImageX
Call image1.ReadImage('some_file_name')
```

Note the keyword Call! It's necessary in Visual Basic if the called method doesn't return a value. The other way of initialization would be using another object's method:

```
Dim image1 As New HImageX
Dim region1 As HRegionX
Call image1.ReadImage('some_file_name')
Set region1 = image1.Threshold(128, 255)
```

There are two important things here. First, the keyword Set, which replaces the Call keyword when the called method returns another COM object (in this case a region). Secondly, the second variable declaration omits the keyword New because the corresponding variable does not need to instantiate an object at declaration time. Instead, this is achieved within the operator Threshold, which creates a new COM object itself and passes a reference to this object as its return value.

HALCON/COM objects get destroyed as soon as no variable references them anymore. For local variables, this is the case when they go out of scope (e.g., when a subroutine is left). For global variables, or if an explicit destruction is desired, this has to be done by the user:

```
Dim image1 As New HImageX
Dim region1 As HRegionX
Call image1.ReadImage('some_file_name')
Set region1 = image1.Threshold(128, 255)
Set image1 = Nothing
Set region1 = Nothing
```

Here, both variables are assigned the special Visual Basic keyword 'Nothing' which denotes that they do not reference their related COM objects anymore. These COM objects thus are not referenced at all which leads to their immediate destruction.

There is, of course, a lot more to say about Visual Basic/HALCON programming. Some further aspects might become clear in the example session described in chapter 20 on page 173.

19.7.2 Error Handling

When using Visual Basic, errors can be trapped by an error handler. If no custom error handler is present, Visual Basic itself supplies a default one, which shows a message box containing the textual

error description. Error handlers in Visual Basic can be set with the keyword `On Error`. To trap an error in a portion of code, the appropriate construct could look like this:

```
Dim LastErrorCode As Long
Dim SysObject As New HSystemX

On Error Goto myErrorHandler

<some code>

myErrorHandler:
  ' do something with the error information, for example:
  Debug.Print "Error occurred: " + Err.Description
  LastErrorCode = Err.Number - SysObject.ErrorBaseHalcon
  Resume Next
```

If an error occurs in `<some code>`, an immediate jump to the label `myErrorHandler` is made, where an arbitrary error processing mechanism can be placed. The scheme used in the example tries to model a traditional, "procedural" error recovery strategy, where every function call returns an error code, which has to be checked before program execution can continue. When an error occurs, the error handling code at the corresponding label takes over, writes a status message (the textual error representation) to the Visual Basic window 'Immediate' and stores the error code in a global integer variable. The global Visual Basic object `Err` is the source of information in this case. Afterwards, control is returned to the line following the statement which produced the error via the Visual Basic command `Resume Next`. The next line of code then would be responsible for checking the error code stored in `LastErrorCode`.

We have seen that there are two types of errors: HALCON-related errors and COM-interface-related ones. Since the COM-interface errors have smaller error numbers than the HALCON error codes, the above mechanism would lead to negative numbers. In this case, the produced error code would have to be subtracted from `SysObject.ErrorBaseCOM` to get the correct (interface-related) error code.

Chapter 20

Example Visual Basic Session

In this chapter you will learn how to develop HALCON applications quickly using Microsoft Visual Basic and the HALCON/COM interface. There will be simple steps describing how to

- create a new project, add HALCON/COM, and create the GUI (section 20.1)
- add simple code to read and display an image (section 20.2 on page 175)
- add image processing code (section 20.3 on page 176)
- use the appliaction with HALCON XL (section 20.4 on page 178)

As an additional source of information you are strongly encouraged to have a look at the other examples which are supplied as Visual Basic sources together with HALCON.

If you want to use HALCON/COM inside other programming languages, please have a look at the examples in the subdirectories `delphi` and `mfc` of `%HALCONEXAMPLES%`; they show how to use HALCON/COM within Borland Delphi, or together with Microsoft MFC in Visual C++. Note that the examples using C# or Visual Basic .NET are based on HALCON/.NET.

20.1 First Step: The GUI

Go ahead and

1. Launch Visual Basic. A dialog named `New Project` should appear allowing you to select the type of project you want. Switch to `New` in the tab list, select `Standard EXE` and click `Open`.
2. Select `Project` from the menu bar and click `Components`. A dialog box shows up listing the components installed on your system. Switch to `Controls` in the tab list and place a check next to the item `Halcon/COM library`.
3. Press `F2`. The object browser should appear. See if you can find `HImageX` and browse through some of the corresponding methods. Clicking on a method shows its parameterization as well as a short help text about what it will do in the status area at the bottom of the object browser. Close the object browser.

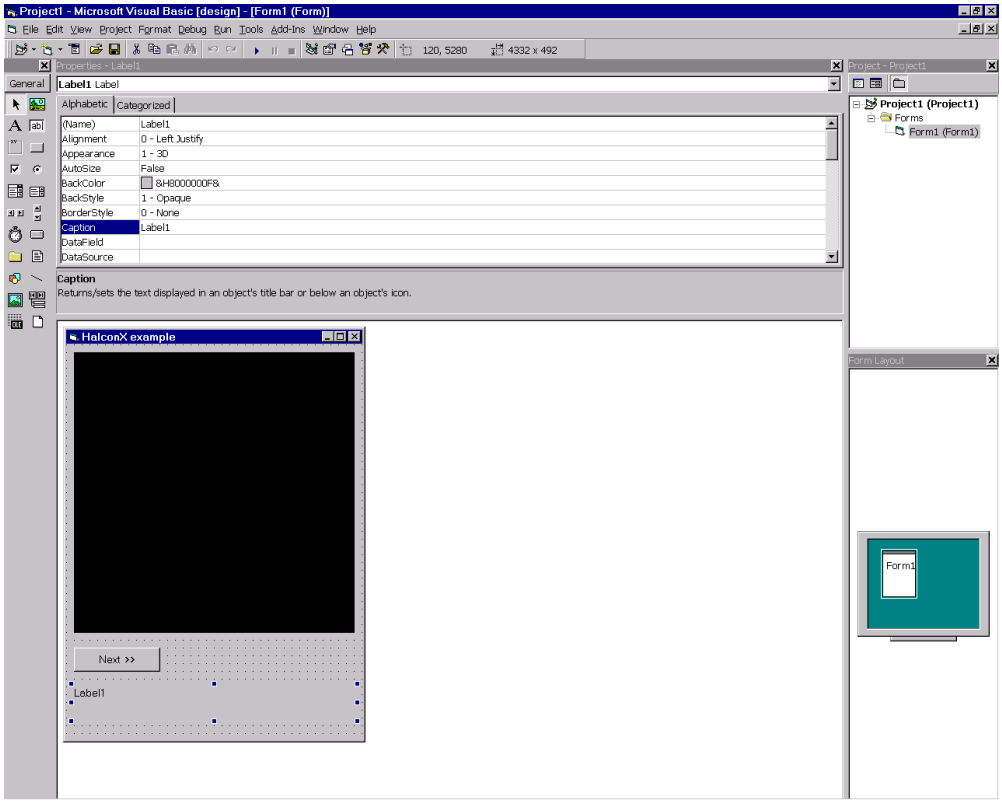


Figure 20.1: Having performed all the steps from section 20.1 you should end up with a setup like this.

4. Have a look at the dialog template ('*form*') showing in the lower half of the screen; it should be titled `Form1`. In the upper half you will discover an area titled `Properties - Form1`. Here you can set and retrieve the active GUI object's (in this case the form's) properties. Click on `Form1` right beside `Caption` and change the string to `HalconX example`. You should see the effect of your action immediately in the caption text of the below form.

5. Grab the form and resize it to a suitable extent.

6. Have a look at the tool bar to the left: Here you can find all the control elements you can place inside your form. They are represented as small icons. Move the mouse cursor over the different icons to see the bubble help revealing their names. You should find an icon showing the HALCON symbol named `HWindowXCtrl`. You guessed it! That is our ActiveX control HALCON window.

7. Activate the `HWindowXCtrl` icon. Draw a rectangular region inside the form | make sure it is approximately square. When releasing the mouse button the square area should turn black.

8. Switch to the `CommandButton` icon (looking like a brick) in the left tool bar. Draw a button inside the form beside or below the HALCON window. Change the button's caption text to `Next` >> in the properties box.

9. Now switch to `Label` in the tool bar and draw a longish rectangular area at the bottom of the form. If you encounter placement difficulties due to lack of form space, you can always resize the form to fit your needs.

10. Resize the form so that it fits around the before created items. Now you have the entire GUI for your application ready to go and your screen should look similar to figure 20.1.

20.2 Second Step: Functionality

Now you have the finished GUI, you should go ahead and make the application do something:

1. Right-click somewhere inside the form and select `View Code`. Another window will pop up over the form with two combo boxes at its top border. Select `Form` in the left combo box. You will see the code to be executed when the form is created.

2. Insert a line into the subroutine:

```
Private Sub Form_Load()
    Label1.Caption = "Click Next to start"
End Sub
```

   You just changed the text the label at the bottom will show when the application is launched.

3. Next we will declare some important variables: Switch back to `(General)` in the left combo box above the source code window and insert in the following lines at the top:

```
Dim Monkey As New HImageX
Dim Window As HWindowX
```

   Some online selection boxes for the desired object type will assist you. We have just created two objects: an `HImageX` and an `HWindowX`. The reason for the keyword in the first line is that we want the `HImageX` object to be instantiated (i.e., memory being allocated for it). This is not necessary for the `HWindowX`, since it is already instantiated; it is the ActiveX control we have drawn inside the form.

4. The object '`Monkey`' is instantiated as we know (although it is not yet initialized with an image), but the variable '`Window`' still refers to nowhere. Insert another line into the subroutine `Form_Load()`:

```
Private Sub Form_Load()
    Set Window = HWindowXCtrl1.HalconWindow
    Label1.Caption = "Click Next to start"
End Sub
```

   Now, the variable '`Window`' refers to the `HWindowX` part of our ActiveX control.

5. Switch to `Command1`. Another subroutine appears, which you complete like this:

```
Private Sub Command1_Click()
    Call Monkey.ReadImage ("monkey")
    Call Window.DispObj(Monkey)
End Sub
```

6. Start your application by pressing F5 and see what happens!

While typing, you will notice a very convenient Visual Basic feature: Since it knows the methods of a class, it allows you to select one from a list, if you wish to do so (see figure 20.2). You will also get assistance in supplying the parameter values for a method call in the right order and with the right types (see figure 20.3); if no type is shown, a VARIANT is required.

Figure 20.2: Visual Basic helping you to select a method.

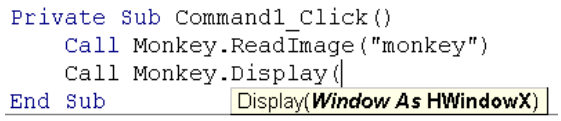


Figure 20.3: Visual Basic helping you with the correct parameters.

20.3 Final Step: More Functionality

What we have now is a very basic application which can't do very much | but it needs only 10 lines of code! Below, we will extend the functionality, turning our application into a small image processing demo:

1. Extend the variable declaration section at the beginning of your listing so it looks like this:

```
Dim Monkey As New HImageX
Dim Window As HWindowX
Dim Region As HRegionX
Dim Eyes As HRegionX
Dim State As Integer
```

Although these declarations are not necessary (Visual Basic declares variables automatically), it is nevertheless a good idea to do so.

2. Select the subroutine `Command1_Click()` and modify it like this:

```
Private Sub Command1_Click()
If State = 3 Then
    End
End If

If State = 2 Then
    Set Eyes = Region.SelectShape("area", "and", 500, 50000)
    Set Eyes = Eyes.SelectShape("anisometry", "and", 1, 1.7)
    Call Window.DispObj(Monkey)
    Call Window.DispObj(Eyes)
    Label1.Caption = "click Finish to terminate"
    Command1.Caption = "Finish"
    State = 3
End If

If State = 1 Then
    Set Region = Monkey.Threshold(128, 256)
    Set Region = Region.Connection()
    Call Window.SetColored(12)
    Call Window.DispObj(Region)
    Label1.Caption = "Next, the ape's eyes will be selected"
    State = 2
End If

If State = 0 Then
    Call Monkey.ReadImage("monkey")
    Call Window.DispObj(Monkey)
    Label1.Caption = "Next, the image will be segmented into
                     several regions"
    State = 1
End If

End Sub
```

3. Run your little program and enjoy a guided tour through a very common image processing example.

20.4 Using HALCON XL

From HALCON 9.0 on, there exists a second version, HALCON XL, which is optimized for large images.

Please note that you should **use HALCON XL only when you need its features**.

In order to use the COM interface of HALCON XL in your Visual Basic application (or in other environments like Borland Delphi, Visual C++, or .NET), all you need to do is to register the corresponding DLL `halconxxl.dll`, e.g., via the dialog `Start` ▷ `Run` together with the Windows Explorer: In the latter, "open" the directory `bin\x86-win32` of the folder where you installed HALCON. Now, type `regsvr32` the dialog `Run` and then drag and drop `halconxxl.dll` from the Explorer into the dialog, where it automatically appears with the full path. To execute the command, click `OK`.

Now, HALCON XL is automatically used whenever you add HALCON/COM to the `Components` of a Visual Basic project. Moreover, it is also used automatically in all projects and executables that were created before you registered `halconxxl.dll`. The reason for this is that, from the point of view of a COM application, the two DLLs `halconx.dll` and `halconxxl.dll` are identical, therefore one can replace the other directly. To check which one is currently registered, open the dialog `Components` via the menu `Project` and select `Halcon/COM library`; below the list box, the corresponding DLL is displayed.

20.5 Other Examples

Under `vb6\Tools\Matching\` you can find an example showing how to use shape-based matching in HALCON/COM.

Part VI

Programming With HALCON/C

Chapter 21

Introducing HALCON/C

HALCON/C is the interface of the image analysis system HALCON to the programming language C. Together with the HALCON library, it allows to use the image processing power of HALCON inside C programs.

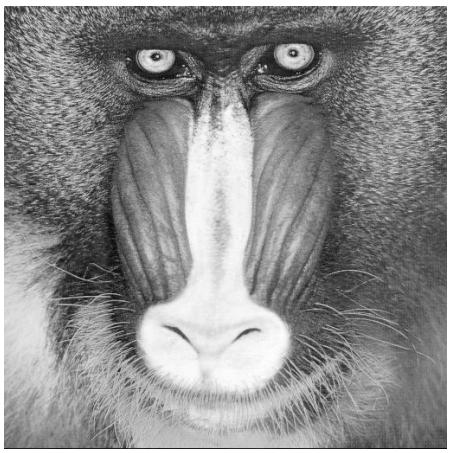
This part is organized as follows: We start with a first example program to show you how programming with HALCON/C looks like. Chapter 22 on page 183 introduces the four different parameter classes of HALCON operators. We will explain the use of HALCON tuples (section 22.2.2 on page 186) for supplying operators with tuples of control parameters in great detail: Using tuples, the two calls to `select_shape` in our example program could be combined into only one call. Chapter 23 on page 195 is dedicated to the return values of HALCON operators. Chapter 24 on page 197 gives an overview over all the include files and C libraries necessary for compiling C programs and shows how to create a stand-alone application. Finally, chapter 25 on page 203 contains example solutions for some common problems in image processing (like edge detection).

21.1 A First Example

Figure 21.1 depicts the example C program together with the input image and the results. The goal is to find the eyes of the monkey by segmentation. The segmentation result is shown in figure 21.1 on the upper right side.

The program is quite self-explanatory. We will describe the basic principles nevertheless: First, all image pixels with gray values greater than 128 are selected. Then all connected components of the region formed by these pixels are calculated. The corresponding HALCON operator calculates a region tuple, and thus splits the image in different regions (objects). From these, the mandrill's eyes are selected by their area and shape.

This example shows how easy it is to integrate HALCON operators in any C program. Their use is very intuitive: Users don't have to think about the basic data structures and algorithms involved. And since all HALCON operators are hardware independent, users don't even have to care about things like different I/O devices. HALCON has its own memory management and provides a sophisticated runtime environment.



```
#include "HalconC.h"

main()
{
  Hobject mandrill,thresh,conn,area,eyes;  /* required objects           */
  Hlong    WindowHandle;

  open_window(0,0,512,512,0,"visible","",&WindowHandle);  /* open window */
  read_image(&mandrill,"monkey");     /* read input image ("monkey") */
  disp_image(mandrill,WindowHandle);    /* display input image          */
  get_mbutton(WindowHandle,_,_,_);      /* wait for mouse click         */

  /* Select image region with pixels in [128,255]                       */
  threshold(mandrill,&thresh,128.0,255.0);
  connection(thresh,&conn);             /* compute connected components  */

  /* select regions with an area of at least 500 pixels                 */
  select_shape(conn,&area,"area","and",500.0,90000.0);

  /* select the eyes in these regions by using the anisometry feature   */
  select_shape(area,&eyes,"anisometry","and",1.0,1.7);
  disp_region(eyes,WindowHandle);       /* display result               */

  get_mbutton(WindowHandle,NULL,NULL,NULL); /* wait for mouse click     */
  close_window(WindowHandle);           /* close window                 */

  /* delete image objects from the Halcon database                      */
  clear_obj(mandrill); clear_obj(thresh); clear_obj(conn);
  clear_obj(area); clear_obj(eyes);
}
```

Figure 21.1: Example program with input image (upper left) and segmentation results (upper right).

Chapter 22

The HALCON Parameter Classes

HALCON distinguishes four different classes of operator parameters:

- Input image objects
- Output image objects
- Input control parameters
- Output control parameters

Input parameters are passed *by value*, output parameters are passed *by reference* (using the &-operator). An exception to this rule are output control parameters of type `char*`. Here, the caller has to provide the memory and only a pointer to that memory is passed to the operator.

Most HALCON operators can also be called using tuples of parameters instead of single values (so-called tuple mode). Take the operator `threshold` from our example program in the previous chapter, which segments an image and returns the segmented region: If you pass a tuple of images, it will return a tuple of regions, one for each input image. However, in contrast to HDevelop and other programming interfaces, in HALCON/C the tuple mode must be selected explicitly by prefixing the operator with `T_` and by using tuples for all control values (see section 22.2 on page 185 for more details). Whether an operator can be called in tuple mode can be seen in the HALCON reference manual.

HALCON/C provides the data structure `Htuple` for tuples of control parameters (see section 22.2.2 on page 186 for details) and the data structure `Hobject` for image objects (single objects as well as object tuples — see section 22.1).

22.1 Image objects

By using image objects, HALCON provides an abstract data model that covers a lot more than simple image arrays.

Basically, there are two different types of image objects:

- Images
- Regions

A region consists of a set of coordinate values in the image plane. Regions do not need to be connected and may include "holes." They may even be larger than the image format. Internally, regions are stored in the so-called runlength encoding.

Images consist of at least one image array and a region, the so-called *domain*. The domain denotes the pixels that are "defined" (i.e., HALCON operators working on gray values will only access pixels in this region). But HALCON supports multi-channel images, too: Images may consist of an (almost) arbitrary number of channels. An image coordinate therefore isn't necessarily represented by a single gray value, but by a vector of up to n gray values (if the coordinate lies within the image region). This may be visualized as a "stack" of image arrays instead of a single array. RGB- or voxel-images may be represented this way.

HALCON provides operators for region transformations (among them a large number of morphological operators) as well as operators for gray value transformations. Segmentation operators are the transition from images (gray values) to regions.

HALCON/C provides the data type `Hobject` for image objects (both images and regions). In fact, `Hobject` is a surrogate of the HALCON database containing all image objects. Input image objects are passed to the HALCON operators *by value* as usual, output image objects are passed *by reference*, using the &-operator. Variables of type `Hobject` may be a single image object as well as tuples of image objects. Single objects are treated as tuples with length one.

Of course, users can access specific objects in an object tuple, too. To do so, it is necessary to extract the specific object key (converted to integer) first, using the operators `obj_to_integer` or `copy_obj`. The number of objects in a tuple can be queried with `count_obj`. To convert the keys (returned from `obj_to_integer`) back to image objects again, the operator `integer_to_obj` has to be used. It may be noted that `integer_to_obj` duplicates the image objects (Don't worry, this doesn't mean necessarily that the corresponding gray value arrays are duplicated too. As long as there is only read-access, a duplication of the references is sufficient). Therefore, all extracted objects have to be deleted explicitly from the HALCON database, using `clear_obj`. Figure 22.1 contains an excerpt from a C program to clarify that approach.

Some HALCON operators like `difference` allow the use of the following specific image objects as input parameters:

`NO_OBJECTS`**:** An empty tuple of image objects.

`EMPTY_REGION`**:** An image object with empty region (area = 0).

`FULL_REGION`**:** An image object with maximal region.

These objects may be returned by HALCON operators, too.

```
...
Hobject   objects;     /* tuple of image objects                  */
Hobject   obj;         /* single image object                     */
Hlong      surrogate;   /* object key, converted to integer        */
Htuple    Tsurrogates; /* tuple of object keys                    */
Htuple    Index,Num;   /* temporary tuple for parameter passing   */
Hlong      i;           /* loop variable                           */
Hlong      num;         /* number of objects                       */

...
count_obj(objects, &num);
/* variant 1: object key -> control parameter                     */
create_tuple_i(&Index,1);
create_tuple_i(&Num,num);
T_obj_to_integer(objects,Index,Num,&Tsurrogates);
for (i=0; i<num; i++)
{
  surrogate = get_i(Tsurrogates,i);
  /* process single object                                        */
}
/* variant 2: copying objects individually                        */
for (i=1; i<=num; i++)
{
  copy_obj(objects,&obj,i,1);
  /* process single object                                        */
}
...
```

Figure 22.1: Accessing the i-th image object in a tuple of image objects.

22.2 Control parameters

HALCON/C supports the following data types as types for control parameters of HALCON operators:

- integers,
- floating point numbers,
- character arrays (strings)

Using control parameter tuples in C isn't as elegant as using image object tuples. To circumvent the missing generic lists in C, it was necessary to introduce two different working modes into HALCON/C: The *simple mode* and the *tuple mode*. If a tuple is necessary for at least one control parameter, the tuple mode has to be used for operator calls. In tuple mode, *all* control parameters of an operator must be passed as type `Htuple` (*Mixing of the two modes is not possible*). The tuple mode also has to be used if the number or type of values that a operators calculates isn't known beforehand.

Mentioning the control parameter types — How is the default type of control parameters determined for a given operator? Basically there are three ways:

1. The operator description in the HALCON reference manual,

2. the HALCON system operator `get_param_info` and
3. the description of the HALCON interface in the file `HProto.h`.

Sometimes the manuals mention more than one possible type. If only integers and floating point numbers are allowed for a parameter, values have to be passed as parameters of type `double`. For all other combinations of types, the tuple mode has to be used.

HALCON operators, that are called in tuple mode are distinguished from simple mode calls by a preceding `T_`. That means,

```
select_shape
```

is a call of the HALCON operator `select_shape` (as described in the HALCON reference manual) in simple mode, whereas

```
T_select_shape
```

is a call of the same operator in tuple mode.

22.2.1 The Simple Mode

In the so-called *simple mode*, all operators described in the HALCON reference manual can be used in a very intuitive way in your own C programs. All control parameters are variables (or constants) of the data types

- `Hlong` for integers (HALCON type `LONG_PAR`),
- `double` for floating point numbers (`DOUBLE_PAR`) or
- `char*` for character arrays (strings, `STRING_PAR`).

`Hlong` and `double` input control parameters are passed *by value* as usual, the corresponding output control parameters are passed *by reference*, using the &-operator. String parameters are pointers to `char` in both cases. *Please note, that the memory for output control parameters (in particular strings) has to be provided by the caller!* We recommend to allocate memory for at least `1024` characters for string parameters of unknown length. Output parameter values that are of no further interest can be set to `NULL` (e.g.,as in the call `get_mbutton` in figure 21.1 on page 182).

Examples for HALCON operator calls in simple mode can be found in the C programs in figure 22.1 and figure 21.1 on page 182.

22.2.2 The Tuple Mode

We mentioned already that control parameter tuples for HALCON operators need special treatment. In this chapter we will give the details on how to construct and use those tuples. The HALCON reference manual describes a large number of operators that don't operate on single control values but on tuples of

values. Using those operators, it is easy to write very compact and efficient programs, because often it is possible to combine multiple similar operator calls into a single call.

Unfortunately, C provides no generic tuple or list constructor. In contrast, HALCON allows tuples with mixed types as control parameter values (e.g., integers mixed with floating point numbers).

Therefore, in addition to the very intuitive simple mode there is another mode in HALCON/C: the tuple mode. Using this mode is a little more elaborate. If at least one of the control parameters of a HALCON operator is passed as a tuple, the tuple mode has to be used for all control parameters (Mixing of both modes isn't possible). Furthermore, the tuple mode also has to be used if the *number* or *type* of the calculated values aren't known beforehand.

Syntactically, tuple mode is distinguished from simple mode by a `T_` preceding the operator name. For example, calling `disp_circle` in tuple mode is done by

```
T_disp_circle(...).
```

To ease the usage of the tuple mode, HALCON/C provides the abstract data type `Htuple` for control parameter tuples. Objects of type `Htuple` may be constructed using arrays of the types

- `Hlong*` for integer arrays (HALCON type `LONG_PAR`),
- `double*` for floating point arrays (`DOUBLE_PAR`) or
- `char**` for string arrays (strings, `STRING_PAR`)

Additionally, a `MIXED_PAR` array type is supported that can hold an array with any of the three native value types in arbitrary combination. The usage of these four array types is transparent.

Control parameter tuples must be created, deleted, and manipulated using the appropriate HALCON/C procedures *only* (overview in figures 22.2, 22.3, and 22.4).

The rules for parameter passing are valid in tuple mode, too: Input control parameters (type `Htuple`) are passed *by value* as usual, output control parameters are passed *by reference*, using the &-operator. For output parameters that are of no further interest you can pass `NULL`. .

The following sections describe the five most important steps when calling a HALCON operator in tuple mode:

- allocate memory (section 22.2.2.1)
- construct input parameters (section 22.2.2.2)
- call operator (section 22.2.2.3 on page 189)
- process output parameters (section 22.2.2.4 on page 189)
- free memory (section 22.2.2.5 on page 190)

Section 22.2.2.6 on page 192 contains an example.

Finally, section 22.2.2.7 on page 193 describes a generic calling mechanism that can be used in interpreters or graphical user interfaces.

22.2.2.1 Allocate Memory

First, memory must be allocated for all tuples of input control parameters, using `create_tuple` or `create_tuple_type`, respectively (see figures 22.2). Memory for output control parameter tuples is allocated by HALCON/C (a call of `create_tuple` isn't necessary). With `create_tuple_i` etc. you can create a tuple of length 1 and set its value in a single step (see figures 22.3). With `reuse_tuple_i` etc. you can reuse an existing tuple, i.e., destroy and reallocate it and set a single value.

```
void create_tuple(tuple,length)     or     macro CT(tuple,length)
     Htuple    *tuple;
     Hlong      length;
     /* creates a MIXED_PAR tuple that can hold 'length' entries h  */

void create_tuple_type(tuple,length,type)
     Htuple    *tuple;
     Hlong      length;
     INT        type
     /* creates a tuple of 'type' that can hold 'length' entries.
      * 'type' can hold either LONG_PAR, DOUBLE_PAR, STRING_PAR,
      * or MIXED_PAR.                                                */

void destroy_tuple(tuple)           or     macro DT(tuple)
     Htuple    tuple;
     /* deletes a tuple (if the tuple contains string entries,     */
     /* the memory allocated by the strings is freed, too)         */

Hlong length_tuple(tuple)            or     macro LT(tuple)
     Htuple    tuple;
     /* returns the length of a tuple (number of entries)           */

void copy_tuple(input,output)      or     macro CPT(input,output)
     Htuple    input;
     Htuple    *output;
     /* creates a tuple and copies the entries of the input tuple  */

void resize_tuple(htuple,new_length) or   macro RT(htuple,new_length)
     Htuple    *htuple;
     Hlong      new_length;
     /* creates a tuple with the new size and copies the previous entries */
```

Figure 22.2: HALCON/C Htuple procedures (part one).

22.2.2.2 Create Input Parameters

You set tuple elements using the appropriate procedures `set_*`. `set_s`, which insert a string into a tuple, allocates the needed memory by itself, and then copies the string (see figure 22.4).

```
void create_tuple_i(tuple,value)
     Htuple    *tuple;
     Hlong      val;
     /* creates a tuple with specifified integer value            */

void create_tuple_d(tuple,value)
     Htuple    *tuple;
     double    val;
     /* creates a tuple with specifified double value             */

void create_tuple_d(tuple,value)
     Htuple    *tuple;
     char      *val;
     /* creates a tuple with specifified string value             */

void reuse_tuple_i(tuple,val)
     Htuple    *tuple;
     Hlong      val;
     /* reuses a tuple with specifified integer value             */

void reuse_tuple_d(tuple,val)
     Htuple    *tuple;
     double    val;
     /* reuses a tuple with specifified double value              */

void reuse_tuple_s(tuple,val)
     Htuple    *tuple;
     char      *val;
     /* reuses a tuple with specifified string value              */
```

Figure 22.3: HALCON/C Htuple procedures (part two).

22.2.2.3 Call Operator

Then, the HALCON operator is actually called. The operator name is (as already explained) preceded by a `T_` to denote tuple mode.

22.2.2.4 Process Output Parameters

Further processing of the output parameter tuples takes place, using the procedures `length_tuple`, `get_type` and `get_*` (see figure 22.4). When processing strings (using `get_s`), please note that the allocated memory is freed automatically upon deleting the tuple with `destroy_tuple`. If the string has to be processed even after the deletion of the tuple, the whole string must be copied first. The maximal string length (incl. termination character "\0") in HALCON is `MAX_STRING` (1024 in HALCON version 11.0).

22.2.2.5 Free Memory

Finally the memory allocated by all the tuples (input and output) has to be freed again. This is done with `destroy_tuple`. If you still need the values of the tuple variables, remember to copy them first. Now, the whole series can start again — using different or the same tuple variables.

```
void set_i(tuple,val,index)         or     macro SI(tuple,val,index)
     Htuple    tuple;
     Hlong      val;
     Hlong      index;
     /* inserts an integer with value 'val' into a tuple at        */
     /* position 'index' ('index' in [0,length_tuple(tuple) - 1])  */

void set_d(tuple,val,index)         or     macro SD(tuple,val,index)
     Htuple    tuple;
     double    val;
     Hlong      index;
     /* inserts a double with value 'val' into a tuple at          */
     /* position 'index' ('index' in [0,length_tuple(tuple) - 1])  */

void set_s(tuple,val,index)         or     macro SS(tuple,val,index)
     Htuple    tuple;
     char      *val;
     Hlong      index;
     /* inserts a copy of string 'val' into a tuple at             */
     /* position 'index' ('index' in [0,length_tuple(tuple) - 1]). */
     /* The memory necessary for the string is allocated by set_s. */

 int get_type(tuple,index)           or     macro GT(tuple,index)
     Htuple    tuple;
     Hlong      index;
     /* returns the type of the value at position 'index' in the     */
     /* tuple. Possible values: LONG_PAR, DOUBLE_PAR or STRING_PAR   */

 Hlong get_i(tuple,index)             or     macro GI(tuple,index)
     Htuple    tuple;
     Hlong      index;
     /* returns the integer at position 'index' in the tuple          */
     /* (a type error results in a run time error)                     */

 double get_d(tuple,index)           or     macro GD(tuple,index)
        Htuple    tuple;
        Hlong      index;
     /* returns the floating point number at position 'index' in the  */
     /* tuple. (a type error results in a run time error)              */

 char *get_s(tuple,index)            or     macro GS(tuple,index)
      Htuple    tuple;
      Hlong      index;
     /* returns the pointer(!) to the string at position 'index' in   */
     /* the tuple. (a type error results in a run time error)          */

     /* Attention: all indices must be in [0,length_tuple(tuple) - 1] */
```

Figure 22.4: HALCON/C Htuple procedures (part three).

22.2.2.6 Example for the Tuple Mode

An example for the tuple mode can be found in figure 22.5 or the file `example3.c`): The aim is to obtain information about the current HALCON system state. The operator `get_system('?',Values)` (here in HDevelop syntax) returns all system flags with their current values. Since in our case neither number nor type of the output parameters is known beforehand, we have to use tuple mode for the actual operator call in HALCON/C. The rest of the program should be self explanatory.

```
#include "HalconC.h"

main ()
{
  Htuple    In,SysFlags,Info;        /* tuple variables            */
  Hlong      i,num;

  printf("system information:\n");
  create_tuple_s(&In,"?");           /* prepare first query        */
                                     /* only value of 'In': "?"    */
  T_get_system(In,&SysFlags);        /* first query                */
  num = length_tuple(SysFlags);      /* number of system flags     */
  for (i=0; i<num; i++)
  {      /* determine the value of the i-th system flag:          */
     reuse_tuple(&In,get_s(SysFlags,i)) /* prepare query           */
                                      /* insert i-th system flag   */
     printf("%s ",get_s(SysFlags,i)); /* print name               */
     T_get_system(In,&Info);          /* get corresponding info    */
     switch(get_type(Info,0))
     {        /* print the value according to the flag's type:    */
       case LONG_PAR:   printf("(int): %ld\n",get_i(info,0));
                        break;
       case DOUBLE_PAR: printf("(double): %f\n",get_d(info,0));
                        break;
       case STRING_PAR: printf("(string): %s\n",get_s(info,0));
                        break;
     }
     destroy_tuple(Info);             /* free parameter            */
   } /* for(i=... */
   destroy_tuple(In);               /* free parameter            */
 }
```

Figure 22.5: Tuple mode example program: Printing the current HALCON system state.

22.2.2.7 Generic Calling Mechanism

There is also an alternative **generic calling mechanism** for HALCON operators in tuple mode. This mechanism is intended for the use in interpreters or graphical user interfaces:

```
T_call_halcon_by_id(id, ...)
```

calls the HALCON operator `id` in tuple mode, passing input parameters and getting the output parameters (see figure 22.6 for the complete signature). The id of an operator can be requested with `get_operator_id`.

```
/* generic HALCON operator call style:
 * - the operator is called by an id that is returned by get_operator_id;
 *    attention: this id may differ for different HALCON versions
 * - the tuple arrays are passed directly to the call -> this method is
 *   thread-safe
 *-----------------------------------------------------------------------*/
int    get_operator_id(const char* name);

Herror T_call_halcon_by_id(int id,
                           const Hobject in_objs[],
                           Hobject out_objs[],
                           const Htuple in_ctrls[],
                           Htuple out_ctrls[]);
```

Figure 22.6: Generic calling mechanism for the HALCON/C tuple mode.

Chapter 23

Return Values of HALCON Operators

HALCON operator return values (type `Herror`) can be divided into two categories:

- Messages (`H_MSG_*`) and
- Errors (`H_ERR_*`).

HALCON operators return `H_MSG_TRUE`, if no error occurs. Otherwise, a corresponding error value is returned.

Errors in HALCON operators usually result in an exception, i.e., a program abort with the appropriate error message in HALCON/C (default exception handling). However, users can disable this mechanism (with a few exceptions, like errors in `Htuple` operators), using

```
set_check("~give_error");
```

to provide their own error handling routines. In that case, the operator `get_error_text` is very useful: This operator returns the plain text message for any given error number. Finally, the operator

```
set_check("give_error");
```

enables the HALCON error handling again. Several examples showing the handling of error messages can be seen in the file `example5.c`.

Chapter 24

Generation of HALCON/C Applications

The HALCON distribution contains examples for creating an application with HALCON/C++. The following sections show

- the relevant directories and files (section 24.1)
- the list of provided example applications (section 24.2)
- the relevant environment variables (section 24.3 on page 199)
- how to create an executable under Windows (section 24.4 on page 200)
- how to create an executable under Linux (section 24.5 on page 200)

24.1 Relevant Directories and Files

The HALCON distribution contains examples for building an application with HALCON/C. Here is an overview of HALCON/C (Windows notation of paths):

`include\HalconC.h`:
include file; contains all user-relevant definitions of the HALCON system and the declarations necessary for the C interface.

`bin\%HALCONARCH%\halcon.dll`,
`lib\%HALCONARCH%\halcon.lib`:
The HALCON library (Windows).

`bin\%HALCONARCH%\halconc.dll`,
`lib\%HALCONARCH%\halconc.lib`:
The HALCON/C library (Windows).

`bin\%HALCONARCH%\halconxl.dll, halconcxl.dll,`
`lib\%HALCONARCH%\halconxl.lib, halconcxl.lib:`
The corresponding libraries of HALCON XL (Windows).

`lib/$HALCONARCH/libhalcon.so:`
The HALCON library (Linux).

`lib/$HALCONARCH/libhalconc.so:`
The HALCON/C library (Linux).

`lib/$HALCONARCH/libhalconxl.so,libhalconcxl.so:`
The corresponding libraries of HALCON XL (Linux).

`include\HProto.h:`
External function declarations.

`%HALCONEXAMPLES% \c\makefile, makefile.win:`
Example makefiles which can be used to compile the example programs (Linux and Windows, respectively).

`%HALCONEXAMPLES% \c\make.%HALCONARCH%, macros.mak, rules.mak:`
Auxiliary makefiles included by the makefiles listed above.

`%HALCONEXAMPLES% \c\source\`
Directory containing the source files of the example programs.

`%HALCONEXAMPLES% \c\win\examples.dsw:`
Visual Studio workspace containing projects for all examples; the projects themselves are placed in subdirectories (Windows only).

`%HALCONEXAMPLES% \c\bin\%HALCONARCH%\`
Destination of the example programs when compiled and linked using the makefiles.

`images\:`
Images used by the example programs.

`help\operators_*:`
Files necessary for online information.

`doc\*:`
Various manuals (in subdirectories).

24.2 Example Programs

There are several example programs in the HALCON/C distribution (`%HALCONEXAMPLES% \c\source\`). To experiment with these examples we recommend to create a private copy in your working directory.

`example1.c`	reads an image and demonstrates several graphics operators.

`example2.c`	introduces several image processing operators.
`example3.c`	is an example for the usage of the tuple mode.
`example4.c`	shows more (basic) image processing operators like the sobel filter for edge detection, region growing, thresholding, histograms, the skeleton operator, and the usage of different color lookup tables.
`example5.c`	describes the HALCON messages and error handling.
`example6.c`	demonstrates the generic calling interface for the tuple mode (`T_call_halcon_by_id`).
`example7.c`	describes the handling of RGB images.
`example8.c`	demonstrates the creation of an image from user memory.
`example9.c`	describes some additional handling of RGB images.

A special case is the example program `example_multithreaded1.c`. It demonstrates the use of HALCON in a multithreaded application. Please note, that it does not make sense to run the example on a single-processor or single-core computer.

24.3 Relevant Environment Variables

In the following, we briefly describe the relevant environment variables; see the Installation Guide, section A.2 on page 64, for more information, especially about how to set these variables. Note, that under Windows, all necessary variables are automatically set during the installation.

While a HALCON program is running, it accesses several files internally. To tell HALCON where to look for these files, the environment variable `HALCONROOT` has to be set. `HALCONROOT` points to the HALCON home directory; it is also used in the sample makefile.

The variable `HALCONARCH` describes the platform HALCON is used on. Please refer to section 1.1 on page 13 for more information.

The variable `%HALCONEXAMPLES%` indicates where the provided examples are installed.

If user-defined packages are used, the environment variable `HALCONEXTENSIONS` has to be set. HALCON will look for possible extensions and their corresponding help files in the directories given in `HALCONEXTENSIONS`.

Two things are important in connection with the example programs: The default directory for the HALCON operator `read_image` to look for images is `%HALCONROOT%\images`. If the images reside in different directories, the appropriate path must be set in `read_image` or the default image directory must be changed, using `set_system("image_dir","...")`. This is also possible with the environment variable `HALCONIMAGES`. It has to be set before starting the program.

The second remark concerns the output terminal under Linux. In the example programs, no host name is passed to `open_window`. Therefore, the window is opened on the machine that is specified in the

environment variable DISPLAY. If output on a different terminal is desired, this can be done either directly in open_window(...,"hostname",...) or by specifying a host name in DISPLAY.

In order to link and run applications under Linux, you have to include the HALCON library path $HALCONROOT/lib/$HALCONARCH in the system variable LD_LIBRARY_PATH.

24.4 Creating Applications Under Windows

Your own C programs that use HALCON operators must include the file HalconC.h, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C interface. Do this by adding the command

```
#include "HalconC.h"
```

near the top of your C file. In order to create an application you must link the library halconc.lib/.dll to your program.

The example projects show the necessary Visual C++ settings. For the examples the project should be of the WIN 32 ConsoleApplication type. Please note that the Visual C++ compiler implicitly calls "Update all dependencies" if a new file is added to a project. Since HALCON runs under Linux as well as under Windows, the include file HalconC.h includes several Linux-specific headers as well if included under Linux. Since they don't exist under Windows, and the Visual C++ compiler is dumb enough to ignore the operating-system-specific cases in the include files, you will get a number of warning messages about missing header files. These can safely be ignored.

Please assure that the stacksize is sufficient. Some sophisticated image processing problems require up to 1 MB stacksize, so make sure to set the settings of your compiler accordingly (See your compiler manual for additional information on this topic).

HALCON XL applications: If you want to use HALCON XL, you have to link the libraries halconxl.lib/.dll and halconcxl.lib/.dll instead of halcon.lib/.dll and halconc.lib/.dll in your project.

24.5 Creating Applications Under Linux

Your own C programs that use HALCON operators must include the file HalconC.h, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C interface. Do this by adding the command

```
#include "HalconC.h"
```

near the top of your C file. Using this syntax, the compiler looks for HalconC.h in the current directory only. Alternatively you can tell the compiler where to find the file, giving it the -I<pathname> command line flag to denote the include file directory.

To create an application, you have to link two libraries to your program: The library `libhalconc.so` contains the various components of the HALCON/C interface. `libhalcon.so` is the HALCON library.

HALCON XL applications: If you want to use HALCON XL, you have to link the libraries `libhalconcxl.so` and `libhalconxl.so` instead.

Please take a look at the example makefiles for suitable settings. If you call `gmake` without further arguments, the example application `example1` will be created. To create the other example applications (e.g., `example2`), call

```
make example2
```

You can use the example makefiles not only to compile and link the example programs but also your own programs (called e.g. `test.c`) by calling

```
make test
```

You can link the program to the HALCON XL libraries by adding `XL=1` to the make command, for example

```
make test XL=1
```

Chapter 25

Typical Image Processing Problems

This final chapter shows the possibilities of HALCON and HALCON/C on the basis of several simple image processing problems.

25.1 Thresholding

One of the most common HALCON operators is the following:

```
read_image(&Image,"File_xyz");
threshold(Image,&Thres,0.0,120.0);
connection(Thres,&Conn);
select_shape(Conn,&Result,"area","and",10.0,100000.0);
```

Step-by-step explanation of the code:

- First, all image pixels with gray values between 0 and 120 (channel 1) are selected.
- The remaining image regions are split into connected components.
- By suppressing regions that are too small, noise is eliminated.

25.2 Detecting Edges

The following HALCON/C sequence is suitable for edge detection:

```
read_image(&Image,"File_xyz");
sobel_amp(Image,&Sobel,"sum_abs",3);
threshold(Sobel,&Max,30.0,255.0);
skeleton(Max,&Edges);
```

Some remarks about the code:

- Before filtering edges with the sobel operator, a low pass filter may be useful to suppress noise.
- Apart from the sobel operator, filters like `edges_image`, `roberts`, `bandpass_image` or `laplace` are suitable for edge detection, too.
- The threshold (30.0, in this case) has to be selected depending on the actual images (or depending on the quality of the edges found in the image).
- Before any further processing, the edges are reduced to the width of a single pixel, using `skeleton`.

25.3 Dynamic Threshold

Among other things, the following code is suitable for edge detection, too:

```
read_image(&Image,"File_xyz");
mean_image(Image,&Lp,11,11);
dyn_threshold(Image,Lp,&Thres,5.0,"light");
```

- The size of the filter mask (11 x 11, in this case) depends directly on the size of the expected objects (both sizes are directly proportional to each other).
- In this example, the dynamic threshold operator selects all pixels that are at least 5 gray values brighter than their surrounding (11 x 11) pixels.

25.4 Simple Texture Transformations

Texture transformations are used to enhance specific image structures. The behavior of the transformation depends on the filters used (HALCON provides many different texture filters).

```
read_image(&Image,"File_xyz");
Filter = "ee";
texture_laws(Image,&TT,Filter,2,5);
mean_image(TT,&Lp,31,31);
threshold(Lp,&Seg,30.0,255.0);
```

- `mean_image` has to be called with a large mask to achieve a sufficient generalization.
- It is also possible to calculate several different texture transformations and to combine them later, using `add_image`, `mult_image` or a similar operator.

25.5 Eliminating Small Objects

The following morphological operation eliminates small image objects and smoothes the boundaries of the remaining objects:

```
            ...
segmentation(Image,&Seg);
gen_circle(&Mask,100.0,100.0,3.5);
opening(Seg,Mask,&Res);
```

- The size of the circular mask (3.5, in this case) determines the smallest size of the remaining objects.
- It is possible to use any kind of mask for object elimination (not only circular masks).
- `segmentation(...)` is used to denote a segmentation operator that calculates a tuple of image objects (`Seg`).

25.6 Selecting Specific Orientations

Yet another application example of morphological operations is the selection of image objects with specific orientations:

```
          ...
segmentation(Image,&Seg);
gen_rectangle2(&Mask,100.0,100.0,0.5,21.0,2.0);
opening(Seg,Mask,&Res);
```

- The rectangle's shape and size (length and width) determine the smallest size of the remaining objects.
- The rectangle's orientation determines the orientation of the remaining regions (In this case, the main axis and the horizontal axis form an angle of 0.5 rad).
- Lines with an orientation different from the mask's (i.e., the rectangle's) orientation are suppressed.
- `segmentation(...)` is used to denote a segmentation operator that calculates a tuple of image objects (`Seg`).

25.7 Smoothing Region Boundaries

The third (and final) application example of morphological operations covers another common image processing problem — the smoothing of region boundaries and closing of small holes in the regions:

```
          ...
segmentation(Image,&Seg);
gen_circle(&Mask,100.0,100.0,3.5);
closing(Seg,Mask,&Res);
```

- For the smoothing of region boundaries, circular masks are suited best.
- The mask size determines the degree of the smoothing.
- `segmentation(...)` is used to denote a segmentation operator that calculates a tuple of image objects (`Seg`).

Part VII

Using HDevEngine

Chapter 26

Introducing HDevEngine

As the name suggests, HDevEngine is the "engine" of HDevelop. This chapter briefly introduces you to its basic concepts. Chapter 27 on page 213 explains how to use it in C++ applications, chapter 28 on page 229 how to use it in .NET applications (C#, Visual Basic .NET, etc.), and chapter 29 on page 257 how to use it in COM applications (Visual Basic 6.0). Additional information that is independent of the used programming language can be found in chapter 30 on page 269.

What Can You Do With HDevEngine?

With HDevEngine, you can execute complete HDevelop programs or individual procedures from a C++ application or an application that can integrate .NET or COM objects, e.g., C#, Visual Basic .NET, or Visual Basic 6.0. Thus, you can use HDevelop programs not only for prototyping, but also to completely develop *and* run the machine vision part of your application.

Because HDevEngine acts as an interpreter, you can modify the HDevelop program or procedure without needing to compile and link the application (if you don't change the procedure's signature), as would be necessary if you export the program or procedure and integrate the code manually. This means that you can easily update the machine vision part of an application by replacing individual HDevelop files.

What HDevEngine Does Not Do

Note that HDevEngine does not implement the complete functionality of HDevelop, only what is necessary to execute programs and procedures. In particular, it does not implement the display of variables and results in the graphics window, i.e., the internal operators like `dev_display`. However, you can "redirect" these operators to your own implementation. Thus, you can decide which visualization is important and where and how it is to take place in your application.

What is HDevEngine?

HDevEngine is provided as a C++ and COM class library and a .NET assembly. It consists of the following classes:

- `HDevEngine` (C++), `HDevEngine` (.NET), `HDevEngineX` (COM)
  This is the main class of HDevEngine. With it you manage global settings.
- `HDevProgram` (C++), `HDevProgram` (.NET), `HDevProgramX` (COM)
  With this class you load an HDevelop program and get general information about it.
- `HDevProgramCall` (C++), `HDevProgramCall` (.NET), `HDevProgramCallX` (COM)
  With this class you execute a program and get the values of its variables.
- `HDevProcedure` (C++), `HDevProcedure` (.NET), `HDevProcedureX` (COM)
  With this class you load an HDevelop procedure and get general information about it.
- `HDevProcedureCall` (C++), `HDevProcedureCall` (.NET), `HDevProcedureCallX` (COM)
  With this class you pass input parameters to an HDevelop procedure, execute it, and retrieve its output parameters.
- `HDevOperatorImplCpp` (C++), `HDevOperatorImplX` (COM), `IHDevOperators`, `HDevOpMultiWindowImpl`, `HDevOpFixedWindowImpl` (.NET)
  As noted above, HDevEngine does not implement internal HDevelop operators like `dev_display`. All HDevEngine variants provide a class or interface to create your own implementation for those operators that are useful in your application. HDevEngine/.NET also includes two convenience classes that provide a default implementation of the operators.
- `HDevEngineException` (C++), `HDevEngineException` (.NET)
  Instances of this class are "thrown" if an exception occurs inside HDevEngine, e.g., because the application tried to load a non-existing program or because of an error inside an operator in the executed program or procedure.

  Note that in the COM version of HDevEngine, the standard error handling mechanism is used instead of a separate class.

How to Develop Applications With HDevEngine

With HDevEngine, you can execute complete HDevelop programs or individual local or external HDevelop procedures. Which way is better depends on the stage of development and on your task:

- When **developing the image processing part** of your application, you will of course create an HDevelop program. Thus, as a first test of your (programmed) application it is useful to **execute the HDevelop program** via HDevEngine. This test will already assure that the general configuration of your application (environment variables, procedure path, etc.) is correct.

  The HDevelop program itself should of course use the same procedures that you plan to execute from the programmed application.
- After you finished its development, you **integrate the image processing part into your programmed application** by **executing the corresponding HDevelop procedures**. Typically, you display image processing results by using the methods of the underlying HALCON programming language interface, i.e., HALCON/C++ for HDevEngine/C++, HALCON/.NET for HDev-

Engine/.NET (C#, Visual Basic .NET, etc.), or HALCON/COM for HDevEngine/COM (Visual Basic 6.0), but you can also encapsulate recurring display tasks in HDevelop procedures.

- Whether to use local or external procedures depends on the reusability of the procedure. **External procedures** should be used for **widely reusable tasks**, e.g., opening the connection to and configuring the image acquisition device, or for **standard image processing tasks** like bar code or data code reading.

  In contrast, **local procedures** are suitable for **not completely reusable tasks**, e.g., for training and configuring a shape model to find objects. Then, different applications can use their optimized variant of the procedure instead of creating a single procedure with many parameters and internal switches that suits all applications.

  Of course, using local procedures means that you must load the HDevelop program that contains them. However, as noted above, loading and executing the corresponding HDevelop program is a good test of the general configuration of the application.

Parallel Programming With HDevEngine

HDevEngine is thread-safe and reentrant. Settings like the procedure path and the implementation of the display operators are managed globally for all threads by the main HDevEngine class. Threads then typically have their own instance of program or procedure calls. They can share instances of the classes for programs and procedures.

Please have a look at the general information about parallel programming with HALCON in section 2.2 on page 19, in particular the style guide in section 2.2.2 on page 20!

HDevEngine XL

Like HALCON, the language-dependent versions of HDevEngine are provided in two variants: based on HALCON and based on HALCON XL. The latter use the XL versions of the HALCON library and of HALCON/C++, HALCON/.NET, and HALCON/COM, respectively.

Chapter 27

HDevEngine in C++ Applications

This chapter explains how to use HDevEngine in C++ applications. Section 27.1 quickly summarizes some basic information, e.g., how to compile and link such applications. Section 27.2 on page 215 then explains how to use HDevEngine based on examples.

An overview about the classes of HDevEngine and their methods can be found in section 30.1 on page 269.

27.1 How to Create An Executable Application With HDevEngine/C++

You create executable HDevEngine applications in a way similar to normal HALCON/C++ applications. Chapter 13 on page 111 describes this in detail; here, we summarize the most important points and include the extensions for HDevEngine:

- In your application, you include the main header file `HalconCpp.h` and HDevEngine's header file `HDevEngineCpp.h` and use the corresponding namespaces:

```
#include "HalconCpp.h"
#include "HDevEngineCpp.h"

using namespace HalconCpp;
using namespace HDevEngineCpp;
```

- To compile the application, use the following include paths on Windows systems

```
/I "$(HALCONROOT)\include" /I "$(HALCONROOT)\include\hdevengine"
```

and on Linux systems

```
-I$(HALCONROOT)/include -I$(HALCONROOT)/include/hdevengine
```

- Link the following libraries on Windows systems

```
/libpath:"$(HALCONROOT)\lib\$(HALCONARCH)" hdevenginecpp.lib halconcpp.lib
```

and on Linux systems

```
-L$(HALCONROOT)/lib/$(HALCONARCH) -lhdevenginecpp -lhalconcpp -lhalcon
```

and on Mac OS X system

```
-framework HDevEngineCpp -framework HALCONCpp
```

HDevEngine XL applications: If you want to use HDevEngine XL, link the following libraries on Windows systems

```
/libpath:"$(HALCONROOT)/lib/$(HALCONARCH)" hdevenginecppxl.lib halconcppxl.lib
```

and on Linux systems

```
-L$(HALCONROOT)/lib/$(HALCONARCH) -lhdevenginecppxl -lhalconcppxl -lhalconxl
```

and on Mac OS X system

```
-framework HDevEngineCppxl -framework HALCONCppxl
```

HALCON/C++ (legacy)

If you want to use HDevEngine with HALCON/C++ (legacy), note the following changes:

- HALCON/C++ (legacy) uses a different namespace:

```
using namespace Halcon;
```

- To compile the application, use the following include paths on Windows systems

```
/I "$(HALCONROOT)\include" /I "$(HALCONROOT)\include\hdevengine10"
```

and on Linux systems

```
-I$(HALCONROOT)/include -I$(HALCONROOT)/include/hdevengine10
```

- Link the following libraries on Windows systems

```
/libpath:"$(HALCONROOT)\lib\$(HALCONARCH)" hdevenginecpp10.lib halconcpp10.lib
```

and on Linux systems

```
-L$(HALCONROOT)/lib/$(HALCONARCH) -lhdevenginecpp10 -lhalconcpp10 -lhalcon
```

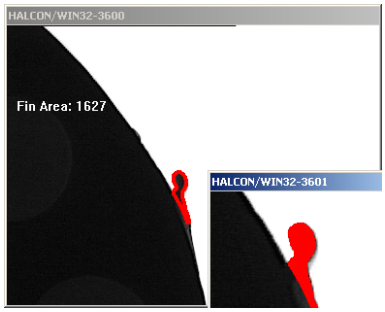


Figure 27.1: Executing an HDevelop program that detects fins on a boundary.

27.2 How to Use HDevEngine/C++

This section explains how to employ HDevEngine based on example applications, which reside in the subdirectory `%HALCONEXAMPLES%\hdevengine\cpp`. Like the examples for HALCON/C++ described in chapter 13 on page 111, they are provided as Visual Studio projects for Windows systems and with makefiles for Linux, Mac OS X, and Windows systems.

The example applications show how to

- execute an HDevelop program (section 27.2.1)
- execute HDevelop procedures (section 27.2.2 on page 217)
- implement display operators (section 27.2.3 on page 221)
- error handling (section 27.2.4 on page 223)

Section 27.2.5 on page 227 contains additional information for creating multithreaded applications using HDevEngine.

27.2.1 Executing an HDevelop Program

In this section, we explain how to load and execute an HDevelop program with HDevEngine. The code fragments stem from the example application `exec_program` (source file `exec_program.cpp`), which checks the boundary of a plastic part for fins. Figure 27.1 shows a screenshot of the application.

27.2.1.1 Step 1: Initialization

First, we include the main header files of HALCON/C++ and of HDevEngine and the corresponding namespaces:

```
#include "HalconCpp.h"
#include "HDevEngineCpp.h"

using namespace HalconCpp;
using namespace HDevEngineCpp;
```

The `main` procedure just calls a procedure that does all the work of the example. First, we create an instance of the main HDevEngine class `HDevEngine`.

```
    HDevEngine my_engine;
```

The path to the HDevelop program and the external procedure path are stored in string variables, with a suitable syntax for the used platform. Note that in Windows applications you can use both `/` and `\` in path strings:

```
    char              *halcon_examples_env = getenv("HALCONEXAMPLES");
    std::string       halcon_examples;

    if (halcon_examples_env == NULL || strlen(halcon_examples_env) == 0)
    {
      halcon_examples = (std::string)getenv("HALCONROOT") + "/examples";
    }
    else
    {
      halcon_examples = (std::string)halcon_examples_env;
    }
    std::string program_path(halcon_examples), ext_proc_path(halcon_examples);

    program_path  += "/hdevengine/hdevelop/fin_detection.hdev";
    ext_proc_path += "/hdevengine/procedures";
```

If the HDevelop program calls external procedures, you must **set the external procedure path** with the method `SetProcedurePath`:

```
    my_engine.SetProcedurePath(ext_proc_path.c_str());
```

27.2.1.2 Step 2: Load Program

Now, we create an instance of the class `HDevProgram` and **load the HDevelop program** with the method `LoadProgram`. The call is encapsulated in a `try...catch`-block to handle exceptions occurring in the HDevEngine method, e.g., because the file name was not specified correctly. A detailed description of error handling can be found in section 27.2.4 on page 223.

```
  HDevProgram my_program;
try
{
  my_program.LoadProgram(program_path.c_str());
}
catch (HDevEngineException& hdev_exception)
  ...
```

27.2.1.3 Step 3: Execute Program

If the program could be loaded successfully, we **execute the program** with the method `Execute` and store the returned instance of the class `HDevProgramCall` in a variable for later use:

```
HDevProgramCall prog_call = my_program.Execute();
```

27.2.1.4 Step 4: Get Results

That's all you need to do to execute an HDevelop program. You can also access its "results", i.e., its variables with the method `GetCtrlVarTuple`. In the example program, the area of the extracted fin is queried and then displayed:

```
HTuple result = prog_call.GetCtrlVarTuple("FinArea");
printf("\nFin Area: %f\n\n",result[0].D());
```

Note that program variables can only be accessed when the program has terminated.

27.2.1.5 General: Display Results

How to display results while the program is running is described in section 27.2.3 on page 221.

27.2.2 Executing HDevelop Procedures

This section describes example applications that execute HDevelop procedures:

- a single external procedure (section 27.2.2.1) and
- multiple local and external procedures (section 27.2.2.8 on page 221).

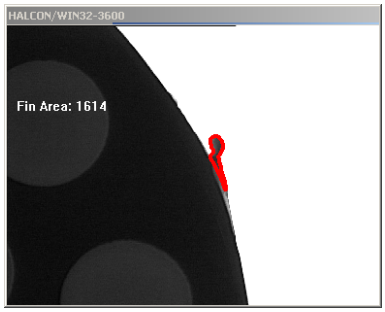


Figure 27.2: Executing an external HDevelop procedure that detects fins on a boundary.

27.2.2.1 Executing an External HDevelop Procedure

In this section, we explain how to load and execute an external HDevelop procedure with HDevEngine. The code fragments in the following stem from the example application `exec_extproc` (source file `exec_extproc.cpp`), which, like the example described in the previous section, checks the boundary of a plastic part for fins. Figure 27.2 shows a screenshot of the application.

In contrast to the previous example, the result display is programmed explicitly in HALCON/C++ instead of relying on the internal display operators. How to provide your own implementation of the internal display operators is described in section 27.2.3 on page 221.

27.2.2.2 Step 1: Initialization

As when executing an HDevelop program, we include the main header files of HALCON/C++ and of HDevEngine and the namespaces. In the main procedure, we temporarily create an instance of the main HDevEngine class `HDevEngine` and directly **set the external procedure path** with the method `SetProcedurePath` (code for constructing the path omitted):

```
#include "HalconCpp.h"
#include "HDevEngineCpp.h"

using namespace HalconCpp;
using namespace HDevEngineCpp;

int main(int argc, char *argv[])
{
  char              *halcon_examples_env = getenv("HALCONEXAMPLES");
  std::string       halcon_examples;

  if (halcon_examples_env == NULL || strlen(halcon_examples_env) == 0)
  {
    halcon_examples = (std::string)getenv("HALCONROOT") + "/examples";
  }
  else
  {
    halcon_examples = (std::string)halcon_examples_env;
  }
  std::string ext_proc_path(halcon_examples);
  ...
  HDevEngine().SetProcedurePath(ext_proc_path.c_str());

  DetectFin();
  return 0;
}
```

27.2.2.3 Step 2: Load Procedure

In the "action" routine, we **load the external procedure** with the constructor of the class `HDevProcedure`, specifying the name of the procedure, and store the returned procedure call in an instance of the class `HDevProcedureCall`. The call is encapsulated in a `try...catch`-block to handle exceptions occurring in the constructor, e.g., because the file name or the procedure path was not specified correctly. A detailed description of error handling can be found in section 27.2.4 on page 223.

```
void DetectFin()
{
  try
  {
    HDevProcedure     proc("detect_fin");
    HDevProcedureCall proc_call(proc);
```

Before executing the procedure, we **open and initialize the graphics window** in which the results are to be displayed and load an example image sequence:

```
const char* image_sequ_str = "fin";

HWindow win(00,100,384,288);
win.SetPart(0,0,575,767);
win.SetDraw("margin");
win.SetLineWidth(4);

HFramegrabber fg("File",1,1,0,0,0,0,"default",-1,"default",-1,"default",
                 image_sequ_str,"default",-1,-1);
```

27.2.2.4 Step 3: Set Input Parameters Of Procedure

Each image should now be processed by the procedure, which has the following signature, i.e., it expects an image as (iconic) input parameter and returns the detected fin region and its area as iconic and control output parameter, respectively:

```
procedure detect_fin (Image: FinRegion: : FinArea)
```

We **pass the image as input object** by storing it in the instance of `HDevProcedureCall` with the method `SetInputIconicParamObject`. Which parameter to set is specified via its index (starting with 1); there is also a method to specify it via its name (see section 30.1.5 on page 278):

```
for (long i=0; i<3; i++)
{
  HImage image = fg.GrabImage();

  proc_call.SetInputIconicParamObject(1,image);
```

As as alternative to passing parameters, you can also use **global variables** in HDevEngine (compare the HDevelop User's Guide, section 8.3.1 on page 341). You set the value of a global variable with the methods `SetGlobalIconicVarObject` or `SetGlobalCtrlVarTuple` and query it with the methods `GetGlobalIconicVarObject` and `GetGlobalCtrlVarTuple`.

27.2.2.5 Step 4: Execute Procedure

Now, we **execute the procedure** with the method `Execute`.

```
  proc_call.Execute();
```

27.2.2.6 Step 5: Get Output Parameters Of Procedure

If the procedure was executed successfully, we can access its results, i.e., the fin region and its area, with the methods `GetOutputIconicParamObject` and `GetOutputCtrlParamTuple` of the class

HDevProcedureCall; again, you can specify the parameter via its index or name (see section 30.1.5 on page 278).

```
HRegion fin_region = proc_call.GetOutputIconicParamObject(1);
HTuple  fin_area;
proc_call.GetOutputCtrlParamTuple(1,&fin_area);
```

27.2.2.7 Step 6: Display Results Of Procedure

Now, we **display the results in the graphics window**. Note how we access the area by selecting the first element of the returned tuple:

```
char    fin_area_str[200];
sprintf(fin_area_str,"Fin Area: %ld",fin_area[0].L());
win.DispImage(image);
win.SetColor("red");
win.DispRegion(fin_region);
win.SetColor("white");
win.SetTposition(150,20);
win.WriteString(fin_area_str);
```

27.2.2.8 Executing Local and External HDevelop Procedures

The example application exec_procedures (source file exec_procedures.cpp) executes local and external HDevelop procedures with HDevEngine. It mimics the behavior of the HDevelop program described in section 27.2.1 on page 215. The display of results is partly programmed explicitly and partly delegated to an HDevelop procedure, using the implementation of the internal display operators described in section 27.2.3.

Local and external procedures are created and executed in exactly the same way. The only difference is that in order to use a local procedure, you must load the program it is contained in, whereas to load external procedures you must set the procedure path. HDevProcedure provides different constructors to facilitate this task (see section 30.1.4 on page 276).

27.2.3 Display

In this section, we explain how to provide your own implementation of HDevelop's internal display operators. The files my_hdevoperatorimpl.h and my_hdevoperatorimpl.cpp contain an example implementation, which is used in the applications exec_program (source file exec_program.cpp), which was already discussed in section 27.2.1 on page 215, and exec_procedures (source file exec_procedures.cpp).

In fact, HDevEngine does not provide an implementation of the internal display operators but provides the class HDevOperatorImplCpp, which contains empty virtual methods for all those operators that you can implement yourself. The methods are called like the object-oriented version of the operators, e.g.,

DevDisplay for dev_display and have the same parameters (see section 30.1.6 on page 280 for the definition of the class).

The first step towards the implementation is to derive a child of this class and to specify all methods that you want to implement. The example file implements the operators dev_open_window, dev_set_window_extents, dev_set_part, dev_set_window, dev_get_window, dev_clear_window, dev_clear_window, dev_close_window, dev_display, dev_set_draw, dev_set_shape, dev_set_color, dev_set_colored, dev_set_lut, dev_set_paint, and dev_set_line_width:

```
class MyHDevOperatorImpl : public HDevEngineCpp::HDevOperatorImplCpp
{
public:
  virtual int DevOpenWindow(const HalconCpp::HTuple& row,
                            const HalconCpp::HTuple& col,
                            const HalconCpp::HTuple& width,
                            const HalconCpp::HTuple& height,
                            const HalconCpp::HTuple& background,
                            HalconCpp::HTuple* win_id);
  virtual int DevSetWindowExtents(const HalconCpp::HTuple& row,
                                  const HalconCpp::HTuple& col,
                                  const HalconCpp::HTuple& width,
                                  const HalconCpp::HTuple& height);
  virtual int DevSetPart(const HalconCpp::HTuple& row1,
                         const HalconCpp::HTuple& col1,
                         const HalconCpp::HTuple& row2,
                         const HalconCpp::HTuple& col2);
  virtual int DevSetWindow(const HalconCpp::HTuple& win_id);
  virtual int DevGetWindow(HalconCpp::HTuple* win_id);
  virtual int DevClearWindow();
  virtual int DevCloseWindow();
  virtual int DevDisplay(const HalconCpp::HObject& obj);
  virtual int DevSetDraw(const HalconCpp::HTuple& draw);
  virtual int DevSetShape(const HalconCpp::HTuple& shape);
  virtual int DevSetColor(const HalconCpp::HTuple& color);
  virtual int DevSetColored(const HalconCpp::HTuple& colored);
  virtual int DevSetLut(const HalconCpp::HTuple& lut);
  virtual int DevSetPaint(const HalconCpp::HTuple& paint);
  virtual int DevSetLineWidth(const HalconCpp::HTuple& width);
};
```

In addition to these methods, the class contains methods to handle multiple graphics windows. These methods use a second class that manages all open windows. This class is thread-safe and reentrant but not described in detail in this section.

```
  Hlong       GetCurrentWindow()  const;
  size_t      GetCount()          const;
  void        AddWindow(Hlong id);
  Hlong       PopWindow();
  Hlong       SetWindow(Hlong id);

  class WinIdContainer
```

In the executed HDevelop program, two graphics windows are used, one for the main display and one for zooming into the image (see figure 27.1 on page 215).

To use the implementation of `HDevOperatorImplCpp`, you include the header file:

```
#include "my_hdevoperatorimpl.h"
```

With the method `SetHDevOperatorImpl`, you pass an instance of your version of `HDevOperatorImplCpp` to HDevEngine, which then calls its methods when the corresponding operator is used in the HDevelop program or procedure.

```
    my_engine.SetHDevOperatorImpl(new MyHDevOperatorImpl);
```

Now, we take a closer look at the implementation of the display operators in the example. It tries to mimic the behavior in HDevelop: Multiple graphics windows can be open, with one being "active" or "current". The methods for the internal display operators simply call the corresponding non-internal display operator: For example, a call to `dev_display` in the HDevelop program is "redirected" in `DevDisplay` to `disp_obj`, with the iconic object to display and the handle of the active window as parameters:

```
int MyHDevOperatorImpl::DevDisplay(const HObject& obj)
{
  HCkDev(DispObj(obj,GetCurrentWindow()));
}
```

Similarly, `dev_set_draw` is redirected in `DevSetDraw` to `set_draw`:

```
int MyHDevOperatorImpl::DevSetDraw(const HTuple& draw)
{
  HCkDev(SetDraw(GetCurrentWindow(),draw));
}
```

As you can see, these operators can be implemented quite easily. The implementation of the operators for handling graphics windows is not described here; we recommend to use the example implementation as it is because it provides all the necessary functionality for single- and multithreaded applications.

27.2.4 Error Handling

In this section, we take a closer look at exceptions in HDevEngine. The code fragments in the following stem from the example application `error_handling` (source file `error_handling.cpp`), which

provokes different types of exceptions and “catches” them.

HDevEngine “throws” exceptions in form of the class `HDevEngineException`, which contains the type (category) of the exception, a message describing the exception, and, depending on the exception type, information like the name of the executed procedure or the HALCON error number (see section 30.1.7 on page 281 for the declaration of the class).

The example code for displaying information about exceptions in a graphics window is contained in the files `my_error_output.cpp` and `my_error_output.h`. You can use it in your application by including the header file:

```
#include "my_error_output.h"
```

The files provide two procedures. The simpler one displays only the error message and waits for a mouse click to continue:

```
void DispMessage(const char* message)
{
  HWindow win(100,100,ERR_WIN_WIDTH_SIMPLE,ERR_WIN_HEIGHT_SIMPLE,
              NULL,"visible","");
  win.SetPart(0,0,ERR_WIN_HEIGHT_SIMPLE-1,ERR_WIN_WIDTH_SIMPLE-1);
  win.SetColor("yellow");
  win.SetTposition(10,10);
  WriteMessageNL(win,message);

  // wait for mouse click to continue
  win.SetColor("red");
  win.SetTposition(ERR_WIN_HEIGHT_SIMPLE/2+10,ERR_WIN_WIDTH_SIMPLE/2);
  win.WriteString("...click into window to continue");
  win.Click();
}
```

The more complex one prints all available information for the exception (only relevant code shown):

```
void DispErrorMessage(const HDevEngineCpp::HDevEngineException& exception,
                      const char* context_msg/*=NULL*/)
{
  char   text[2000];

  HWindow win(100,100,ERR_WIN_WIDTH_COMPLEX,ERR_WIN_HEIGHT_COMPLEX,
              NULL,"visible","");

  WriteMessageNL(win,exception.Message());

  sprintf(text,"    Error category: <%d : %s>",
          exception.Category(),exception.CategoryText());
  WriteMessageNL(win,text);

  sprintf(text,"    Error number:   <%d>",exception.HalconErrNum());
  WriteMessageNL(win,text);

  sprintf(text,"    Procedure:      <%s>",exception.ExecProcedureName());
  WriteMessageNL(win,text);

  sprintf(text,"        Line:         <%d : %s>",
          exception.ProgLineNum(),exception.ProgLineName());
  WriteMessageNL(win,text);
}
```

This procedure is called when an exception occurs. The example provokes different errors and displays the corresponding information; some of them are described in the following. Figure 27.3 displays an exception that occurred because the application tried to load a non-existing HDevelop program (category `ExceptionFile`).

```
  try
  {
    program.LoadProgram(wrong_program_path.c_str());
  }
  catch (HDevEngineException &hdev_exception)
  {
    DispErrorMessage(hdev_exception,
      "Error #1: Try to load a program that does not exist");
  }
```

The same exception category occurs when a program is loaded whose external procedures are not found (see figure 27.4).

The exception displayed in figure 27.5 occurs because an input iconic parameter is not initialized (category `ExceptionInpNotInit`). It contains very detailed information about where the error occurred and why.

The exception displayed in figure 27.6 on page 227 is provoked by calling an operator with an invalid parameter (category `ExceptionCall`):

With the method `UserData` (see section 30.1.7 on page 281), you can also access user exception data

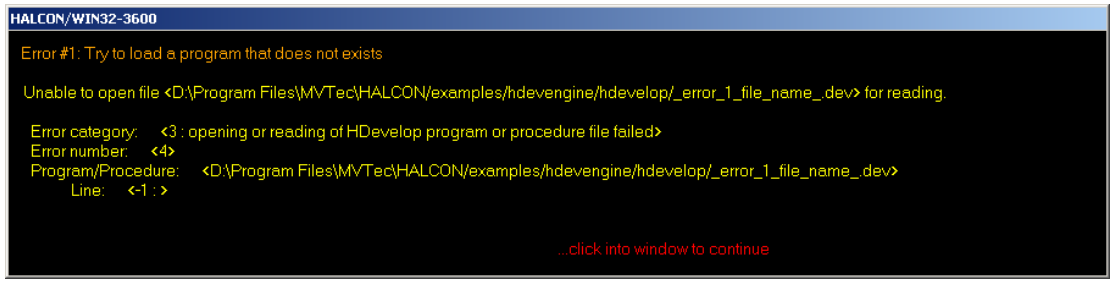


Figure 27.3: Content of the exception if an HDevelop program could not be found.

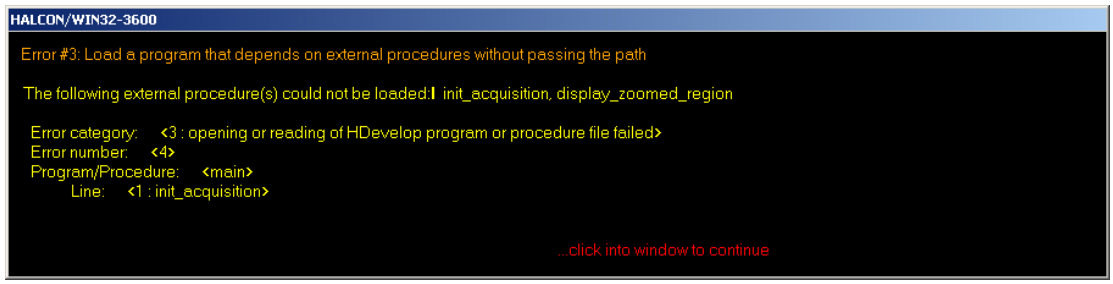


Figure 27.4: Content of the exception if external procedures of an HDevelop program could not be loaded.

that is thrown within an HDevelop program or procedure by the operator `throw` similarly to the operator `dev_get_exception_data`.

Note that you can configure the behavior of HDevEngine when loading programs or procedures that contain invalid lines or unresolved procedure calls with the method `SetEngineAttribute` (see section 30.1.1 on page 270).

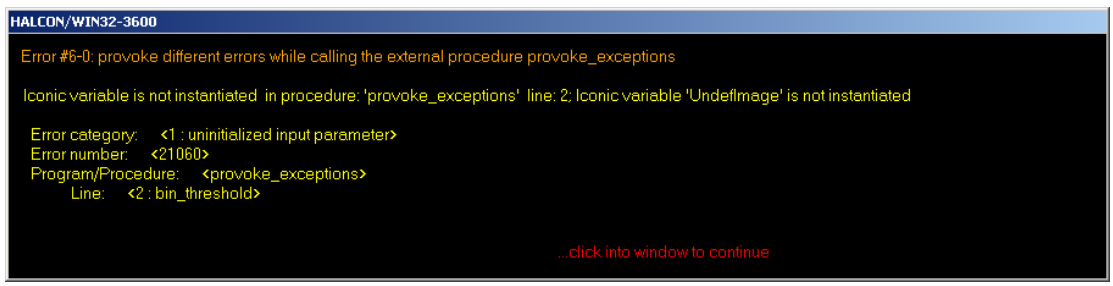


Figure 27.5: Content of the exception if an input parameter was not initialized.

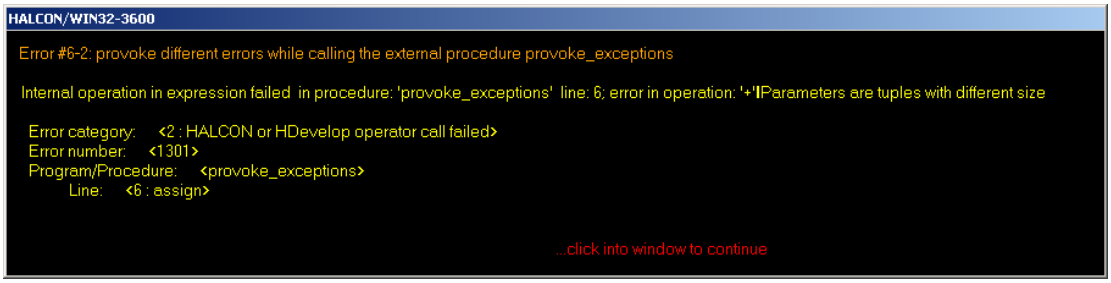


Figure 27.6: Content of the exception if an error occurred in a HALCON operator call.

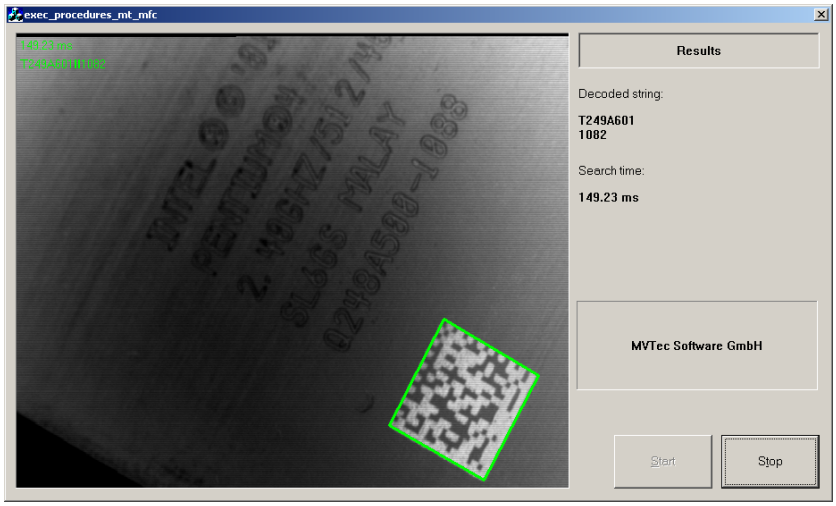


Figure 27.7: Example program with three threads performing image acquisition, data code reading, and visualization in parallel.

27.2.5 Creating Multithreaded Applications

In the example `mfc\exec_procedures_mt_mfc` , three threads execute HDevelop procedures for image acquisition, data code reading, and visualization in parallel. Please have a look at the example source files (in the directory `mfc\exec_procedures_mt_mfc\source\`) to see how the threads synchronize their input and output data.

The example `exec_programs_mt` (source file `exec_programs_mt.cpp`) shows how one or several different HDevelop programs can be executed in different threads in parallel. Note that it is kept very general and does not realize a specific application.

The HDevelop program(s) must be passed as command line arguments. Optionally, you can pass for every program the number of threads and/or how often the program should be performed consecutively within each thread. The command line parameters are explained when calling the executable without parameters.

Chapter 28

HDevEngine in .NET Applications

This chapter explains how to use HDevEngine in C# and Visual Basic .NET applications. Section 28.1 quickly summarizes some basic information about creating HDevEngine applications with Visual Studio .NET and Visual Studio 2005. Section 28.2 then explains how to use HDevEngine/.NET based on examples.

28.1 Basics

To use HDevEngine in Visual Studio .NET, you must

- add a reference to the HALCON/.NET assembly `halcondotnet.dll`, either by adding an instance of `HWindowControl` to the form or by adding the reference directly via the Solution Explorer (also see section 16.2.2 on page 126):
- add a reference to the HDevEngine/.NET assembly `hdevenginedotnet.dll` via the Solution Explorer
- specify the namespace with the following line (also see section 16.2.3 on page 127):

```
using HalconDotNet;
```

HDevEngine XL applications: If you want to use HDevEngine/.NET XL, you must add the XL versions of the HALCON/.NET and HDevEngine/.NET assembly instead.

A short reference of the C++ classes for the HDevEngine can be found in section 30.1 on page 269. The .NET classes are very similar; their exact definition can be seen in the online help of Visual Studio (see section 16.4.1 on page 129).

28.2 Examples

This section explains how to employ HDevEngine/.NET based on example applications for C# and Visual Basic .NET, which reside in the subdirectories `%HALCONEXAMPLES%\hdevengine\c#` and

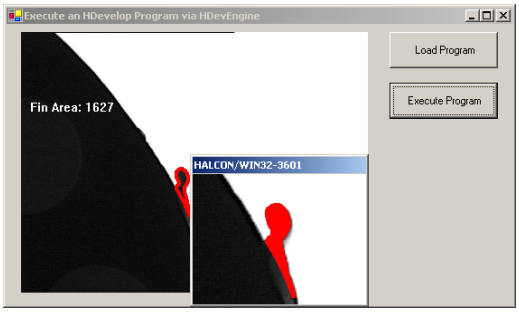


Figure 28.1: Executing an HDevelop program that detects fins on a boundary.

`%HALCONEXAMPLES%\hdevengine\vb.net`. In the following, we describe only the C# examples; the Visual Basic .NET versions are identical except for the standard differences between the two languages. Furthermore, in contrast to the C# versions, the Visual Basic .NET versions do not contain support for Linux.

- executing an HDevelop program (section 28.2.1),
- executing HDevelop procedures (section 28.2.2 on page 232), and
- display operators (section 28.2.3 on page 238),
- error handling (section 28.2.4 on page 238), and
- multithreading (section 28.2.5 on page 241).

28.2.1 Executing an HDevelop Program

In this section, we explain how to load and execute an HDevelop program with HDevEngine. The code fragments stem from the example application `ExecProgram`, which checks the boundary of a plastic part for fins. Figure 28.1 shows a screenshot of the application; it contains two buttons to load and execute the HDevelop program.

28.2.1.1 Step 1: Initialization

First, we create a global instance of the main HDevEngine class `HDevEngine`.

```
private HDevEngine MyEngine = new HDevEngine();
```

Upon loading the form, we store the path to the HDevelop program and set the external procedure path with the method `SetProcedurePath`:

```
String  ProgramPathString;

private void ExecProgramForm_Load(object sender, System.EventArgs e)
{
  string halconExamples;
  string ProcedurePath;
  try
  {
    halconExamples = Environment.GetEnvironmentVariable("HALCONEXAMPLES");
    if (halconExamples == null)
      throw new Exception();
  }
  catch (Exception)
  {
    halconExamples = Environment.GetEnvironmentVariable("HALCONROOT") + @"\examples";
  }
  ProgramPathString = halconExamples +
    @"\hdevengine\hdevelop\fin_detection.hdev";
  ProcedurePath = halconExamples + @"\hdevengine\procedures";
  if (!HalconAPI.isWindows)
  {
    ProcedurePath = ProcedurePath.Replace('\\', '/');
    ProgramPathString = ProgramPathString.Replace('\\', '/');
  }
  MyEngine.SetProcedurePath(ProcedurePath);
}
```

Note that the latter is only necessary if the HDevelop program calls external procedures.

28.2.1.2 Step 2: Load Program

When you click the button to load the HDevelop program, an instance of the class `HDevProgram` is created, with the path of the program as parameter. Furthermore, an instance of `HDevProgramCall` is created for later use. Exceptions occurring in the constructors, e.g., because the file name was not specified correctly, are handled with the standard C# error handling mechanism:

```
private void LoadBtn_Click(object sender, System.EventArgs e)
{
  try
  {
    HDevProgram Program = new HDevProgram(ProgramPathString);
    ProgramCall = new HDevProgramCall(Program);
  }
  catch (HDevEngineException Ex)
  {
    MessageBox.Show(Ex.Message, "HDevEngine Exception");
    return;
  }
}
```

More information on error handling can be found in section 28.2.4 on page 238.

28.2.1.3 Step 3: Execute Program

When you click the button to execute the program, the method `Execute` is called:

```
private void ExecuteBtn_Click(object sender, System.EventArgs e)
{
  try
  {
    ProgramCall.Execute();
  }
  catch (HDevEngineException Ex)
  {
    MessageBox.Show(Ex.Message, "HDevEngine Exception");
    return;
  }
}
```

28.2.1.4 Step 4: Get Results

That's all you need to do to execute an HDevelop program. You can also access its "results", i.e., its variables with the method `GetCtrlVarTuple`. In the example program, the area of the extracted fin is queried and then displayed:

```
  double FinArea;
  FinArea = ProgramCall.GetCtrlVarTuple("FinArea");
  Window.SetTposition(150, 20);
  Window.WriteString("Fin Area: ");
```

Note that program variables can only be accessed when the program has terminated.

28.2.1.5 General: Display Results

How to display results while the program is running is described in section 28.2.3 on page 238.

28.2.2 Executing HDevelop Procedures

This section describes example applications that execute HDevelop procedures:

- a single external procedure (section 28.2.2.1) and
- multiple local and external procedures (section 28.2.2.8 on page 236).

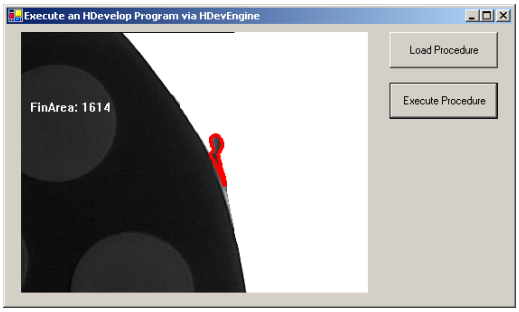


Figure 28.2: Executing an external HDevelop procedure that detects fins on a boundary.

28.2.2.1 Executing an External HDevelop Procedure

In this section, we explain how to load and execute an external HDevelop procedure with HDevEngine. The code fragments in the following stem from the example application `ExecExtProc`, which, like the example described in the previous section, checks the boundary of a plastic part for fins. Figure 28.2 shows a screenshot of the application; it contains two buttons to load and execute the HDevelop procedure.

In contrast to the previous example, the result display is programmed explicitly instead of relying on the internal display operators.

28.2.2.2 Step 1: Initialization

As when executing an HDevelop program, we create a global instance of the main HDevEngine class `HDevEngine` and set the external procedure path with the method `SetProcedurePath` upon loading the form (code for constructing the path omitted):

```
private HDevEngine MyEngine = new HDevEngine();

private void ExecExtProcForm_Load(object sender, System.EventArgs e)
{
  string ProcedurePath;
  ...
  MyEngine.SetProcedurePath(ProcedurePath);
}
```

In contrast to the C++ version of this example application, we want to display the results not in a free-floating graphics window, but within the form, i.e, inside an instance of `HWindowControl` (also see section 16.3 on page 128 and section 16.6 on page 140). For calling the HALCON operators, we declare a global variable of the class `HWindow` for the underlying HALCON window; upon loading the form, we set this variable to the HALCON window in the `HWindowControl` and initialize the window:

```
private HWindow Window;

private void WindowControl_HInitWindow(object sender, System.EventArgs e)
{
  Window = WindowControl.HalconWindow;

  Window.SetDraw("margin");
  Window.SetLineWidth(4);
}
```

28.2.2.3 Step 2: Load Procedure

When you click the button Load, the HDevelop procedure is loaded with the constructor of the class HDevProcedure, specifying the name of the procedure, and a corresponding procedure call is created as an instance of the class HDevProcedureCall. Exceptions occurring in the constructors, e.g., because the file name or the procedure path was not specified correctly, are handled with the standard C# error handling mechanism. More information on error handling can be found in section 28.2.4 on page 238.

```
private void LoadBtn_Click(object sender, System.EventArgs e)
{
  try
  {
    HDevProcedure Procedure = new HDevProcedure("detect_fin");
    ProcCall = new HDevProcedureCall(Procedure);
  }
  catch (HDevEngineException Ex)
  {
    MessageBox.Show(Ex.Message, "HDevEngine Exception");
    return;
  }
}
```

Executing a procedure consists of multiple steps. First, we load an example image sequence:

```
private void ExecuteBtn_Click(object sender, System.EventArgs e)
{
  HFramegrabber Framegrabber = new HFramegrabber();
  Framegrabber.OpenFramegrabber("File", 1, 1, 0, 0, 0, 0, "default",
     -1, "default", -1, "default", "fin.seq", "default", -1, -1);
```

28.2.2.4 Step 3: Set Input Parameters Of Procedure

Each image should now be processed by the procedure, which has the following signature, i.e., it expects an image as (iconic) input parameter and returns the detected fin region and its area as iconic and control output parameter, respectively:

```
procedure detect_fin (Image: FinRegion: : FinArea)
```

We pass the image as an input object by storing it in the instance of `HDevProcedureCall` with the method `SetInputIconicParamObject`. Which parameter to set is specified via its name (as an alternative, you can specify it via its index):

```
HImage Image = new HImage();
HRegion FinRegion;
HTuple FinArea;

for (int i=0; i<=2; i++)
{
  Image.GrabImage(Framegrabber);
  Image.DispObj(Window);

  ProcCall.SetInputIconicParamObject("Image", Image);
```

As as alternative to passing parameters, you can also use **global variables** in HDevEngine (compare the HDevelop User's Guide, section 8.3.1 on page 341). You set the value of a global variable with the methods `SetGlobalIconicVarObject` or `SetGlobalCtrlVarTuple` and query it with the methods `GetGlobalIconicVarObject` and `GetGlobalCtrlVarTuple`.

28.2.2.5 Step 4: Execute Procedure

Now, we execute the procedure with the method `Execute`.

```
  ProcCall.Execute();
```

28.2.2.6 Step 5: Get Output Parameters Of Procedure

If the procedure was executed successfully, we can access its results, i.e., the fin region and its area, with the methods `GetOutputIconicParamRegion` and `GetOutputCtrlParamTuple` of the class `HDevProcedureCall`; again, you can specify the parameter via its name or index. Note that you can get iconic output objects either as instances of the corresponding class (here, `HRegion`) or as instance of `HObject` by using `GetOutputIconicParamObject`.

```
  FinRegion = ProcCall.GetOutputIconicParamRegion("FinRegion");
  FinArea = ProcCall.GetOutputCtrlParamTuple("FinArea");
```

28.2.2.7 Step 6: Display Results Of Procedure

Finally, we display the results in the graphics window:

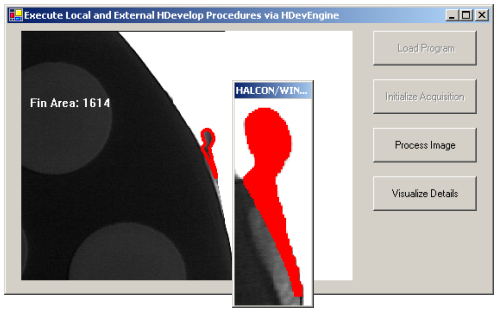


Figure 28.3: Screenshot of the application.

```
    Image.DispObj(Window);
    Window.SetColor("red");
    Window.DispObj(FinRegion);
    Window.SetColor("white");
    Window.SetTposition(150, 20);
    Window.WriteString("FinArea: " + FinArea.D);
  }
```

28.2.2.8 Executing Local and External HDevelop Procedures

The example application `ExecProcedures` executes local and external HDevelop procedures with HDevEngine. It mimics the behavior of the HDevelop program described in section 28.2.1 on page 230. The display of results is partly programmed explicitly and partly delegated to an HDevelop procedure, using the implementation of the internal display operators described in section 28.2.3 on page 238. Figure 28.3 shows a screenshot of the application.

In the following, we briefly describe parts of the code.

Local and external procedures are created and executed in exactly the same way. The only difference is that in order to use a local procedure, you must load the program it is contained in, whereas to load external procedures you must set the procedure path. In the example, the image processing procedure is local, the other external. Note that the code for constructing the program and procedure path is omitted.

```
private HDevProcedureCall InitAcqProcCall;
private HDevProcedureCall ProcessImageProcCall;
private HDevProcedureCall VisualizeDetailsProcCall;

private void ExecProceduresForm_Load(object sender, System.EventArgs e)
{
  string ProcedurePath;
  ...
  MyEngine.SetProcedurePath(ProcedurePath);
}
```

```
private void LoadBtn_Click(object sender, System.EventArgs e)
{
  try
  {
    HDevProgram Program = new HDevProgram(ProgramPathString);

    HDevProcedure InitAcqProc = new HDevProcedure(Program, "init_acquisition");
    HDevProcedure ProcessImageProc = new HDevProcedure(Program, "detect_fin");
    HDevProcedure VisualizeDetailsProc = new HDevProcedure(Program, "display_zoomed_region");

    InitAcqProcCall = new HDevProcedureCall(InitAcqProc);
    ProcessImageProcCall = new HDevProcedureCall(ProcessImageProc);
    VisualizeDetailsProcCall = new HDevProcedureCall(VisualizeDetailsProc);
  ...
}
```

One of the procedures opens the image acquisition device. It returns the corresponding handle, which we store in an instance of the class `HFramegrabber`.

```
HFramegrabber Framegrabber;

private void InitAcqBtn_Click(object sender, System.EventArgs e)
{
  InitAcqProcCall.Execute();
  Framegrabber = new HFramegrabber(InitAcqProcCall.GetOutputCtrlParamTuple("AcqHandle"));
  ...
}
```

In the example application, the device is closed when the application terminates and calls the finalizer of the class `HFramegrabber`, which in turn calls the operator `CloseFramegrabber`. If you use an HDevelop procedure for closing the connection to the device, you would invalidate the handle so that the finalizer raises an exception.

As in the previous example, the results of image processing (button `Process Image`) are displayed "manually" by calling HALCON/.NET operators. In contrast, when you click the button `Visualize Details`, an HDevelop procedure is executed that zooms onto the extracted fin. For this, we pass an implementation of HDevelop's internal display operators (see section 28.2.3 for more information about the implementation classes) and remove it again after the procedure has been executed.

```
private void VisualizeDetailsBtn_Click(object sender, System.EventArgs e)
{
  MyEngine.SetHDevOperators(MyHDevOperatorImpl);
  VisualizeDetailsProcCall.SetInputIconicParamObject("Image", Image);
  VisualizeDetailsProcCall.SetInputIconicParamObject("Region", FinRegion);
  VisualizeDetailsProcCall.SetInputCtrlParamTuple("ZoomScale", 2);
  VisualizeDetailsProcCall.SetInputCtrlParamTuple("Margin", 5);
  VisualizeDetailsProcCall.Execute();
  MyEngine.SetHDevOperators(null);
}
```

The instance of the implementation class is initialized with the HALCON window of the form.

```
private HDevOpMultiWindowImpl MyHDevOperatorImpl;

private void WindowControl_HInitWindow(object sender, System.EventArgs e)
{
  Window = WindowControl.HalconWindow;
  ...
  MyHDevOperatorImpl = new HDevOpMultiWindowImpl(Window);
}
```

28.2.3 Display

In contrast to the C++ (and COM) version of HDevEngine, HDevEngine/.NET already provides convenience implementations of HDevelop's internal display operators in form of two classes:

- `HDevOpFixedWindowImpl` directs all display operators to a single graphics window (passed in the constructor), even if the HDevelop program or procedure uses multiple windows.
- `HDevOpMultiWindowImpl` can handle multiple graphics windows. You can pass an arbitrary number of graphics windows in the constructor; if the HDevelop program or procedure uses more than them, HDevEngine opens additional free-floating windows.

Please note that **these classes must not be used in multithreaded applications** because they are not reentrant. If you need a reentrant version, please discuss your application requirements with your local distributor.

The example program `ExecProgram` uses `HDevOpMultiWindowImpl`. To use this class (or `HDevOpFixedWindowImpl`), you pass an instance of it to `HDevEngine` with the method :

```
private void WindowControl_HInitWindow(object sender, System.EventArgs e)
{
  Window = WindowControl.HalconWindow;

MyEngine.SetHDevOperators(new HDevOpMultiWindowImpl(Window));
}
```

If your application has special display requirements that are not satisfied by the two classes, you can provide your own implementation of the display operators similar to the C++ version of HDevelop (see section 27.2.3 on page 221) by creating a class implementing the interface `IHDevOperators` and overloading its methods `DevOpenWindow`, `DevDisplay`, etc.

Please note that currently you cannot use any form of display operator implementation with Mono (see section 17.3.1 on page 150).

28.2.4 Error Handling

In this section, we take a closer look at exceptions in HDevEngine. The code fragments in the following stem from the example application `ErrorHandling`, which provokes and catches different types of exceptions when you press some buttons. Figure 28.4 shows a screenshot of the application.

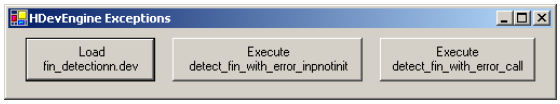


Figure 28.4: Provoking exceptions in HDevEngine .

HDevEngine throws exceptions as instances of the class `HDevEngineException`, which contains the type (category) of the exception, a message describing the exception, and, depending on the exception type, information like the name of the executed procedure or the HALCON error number (also see section 30.1.7 on page 281).

In the example application, the following procedure displays all the information contained in `HDevEngineException` in a message box:

```
private void DisplayException(HDevEngineException Ex)
{
  string FullMessage = "Message: <" + Ex.Message + ">" +
    ",  Error in program / procedure: <" + Ex.ProcedureName + ">" +
    ",  program line: <" + Ex.LineText + ">" +
    ",  line number: <" + Ex.LineNumber + ">" +
    ",  HALCON Error Number: <" + Ex.HalconError + ">";

  string Title = "HDevEngine Exception (Category: " +
    Ex.Category.ToString() + ")";

  MessageBox.Show(FullMessage, Title);
}
```

This procedure is called when an exception occurs; note that the example applications described in the previous sections only display the exception message.

```
try
{
  HDevProgram Program = new HDevProgram(ProgramPathString);
  ProgramCall = new HDevProgramCall(Program);
}

catch (HDevEngineException Ex)
{
  DisplayException(Ex);
  return;
}
```

Figure 28.5 displays an exception that occurred because the application tried to load a non-existing HDevelop program (category `ExceptionFile`). As you can see, only the message contains useful information in this case.

The next exception occurs when executing a procedure in which an input parameter is not initialized (category `ExceptionInpNotInit`):

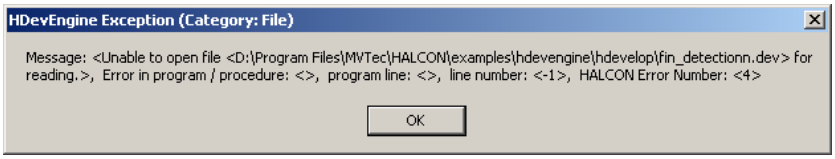


Figure 28.5: Content of the exception if an HDevelop program could not be loaded.

```
procedure detect_fin_with_error_inpnotinit (Image: FinRegion: : FinArea)
  bin_threshold (NotExistingImage, Dark)
  ...
```

Figure 28.6 displays the content of the exception, which now contains very detailed information about where the error occurred and why.

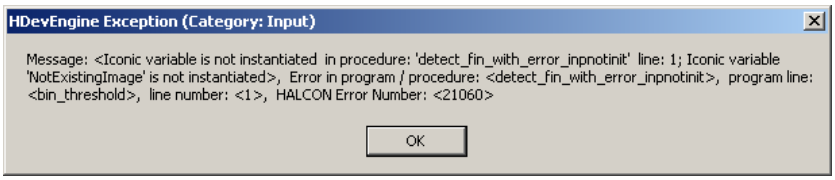


Figure 28.6: Content of the exception if an input parameter was not initialized.

The final exception is provoked by executing a procedure in which the call to the operator `closing_circle` fails because the third parameter is not valid (category `ExceptionCall`):

```
procedure detect_fin_with_error_call (Image: FinRegion: : FinArea)
  bin_threshold (Image, Dark)
  difference (Image, Dark, Background)
  dev_set_color ('blue')
  dev_display (Background)
  closing_circle (Background, ClosedBackground, -1)
  ...
```

Figure 28.7 shows the content of the exception.

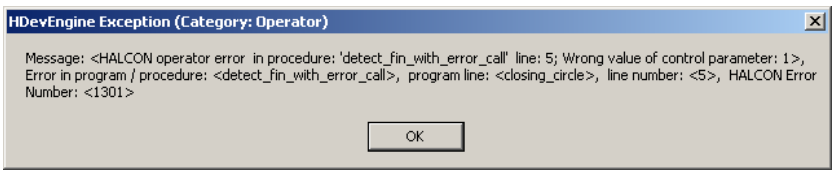


Figure 28.7: Content of the exception if an error occurred in a HALCON operator call.

With the method UserData (see section 30.1.7 on page 281), you can also access user exception data that is thrown within an HDevelop program or procedure by the operator throw similarly to the operator dev_get_exception_data.

Note that you can configure the behavior of HDevEngine when loading programs or procedures that contain invalid lines or unresolved procedure calls with the method SetEngineAttribute (see section 30.1.1 on page 270).

28.2.5 Creating Multithreaded Applications

HALCON provides two C# example applications that use multithreading with HDevEngine/.NET:

- In MultiThreading, the application is sped up by **executing the same HDevelop procedure in parallel** by two threads.
- In contrast, in MultiThreadingTwoWindows **different procedures are executed in parallel**.

The first one is described in detail in section 28.2.5.1. The second one is very similar, thus, in section 28.2.5.2 on page 249 only the differences are described.

In the following, we briefly list the most important rules to observe when creating multithreaded HDevEngine applications. Please also have a look at the general information about parallel programming using HALCON in section 2.2 on page 19, in particular the style guide in section 2.2.2 on page 20!

- When multiple threads execute HDevelop programs in parallel, **each thread must create its own instance of the corresponding** HDevProgramCall.
- **External procedure path and the implementation of HDevelop's display operators are always set globally** for all instances of HDevEngine. We recommend to set them via a separate HDevEngine instance to keep the code more readable.
- Because the **implementation of HDevelop's display operators** can only be set globally, it **must be thread-safe and reentrant**. The classes HDevOpFixedWindowImpl and HDevOpMultiWindowImpl described in section 27.2.3 on page 221 do not fulfill this condition. For a reentrant version please discuss your application requirements with your local distributor.

28.2.5.1 Executing a Procedure in Parallel by Multiple Threads

The example application MultiThreading presented in this section exploits multi-core or multiprocessor systems by executing the same HDevelop procedure (task) in parallel by two threads. The procedure finds bottle caps using shape-based matching.

Figure 28.8 shows an overview of the structure of the application. It consists of four threads: The main thread (i.e., the form) is in charge of the graphical user interface (GUI), which is depicted in figure 28.9. It consists of a HALCON window for the display of results and buttons to initialize, start, and stop the application.

The main thread also initializes the application by training the shape model via an HDevelop procedure and by creating and initializing the other three threads: two processing threads and the so-called control thread, whichs controls the two processing threads.

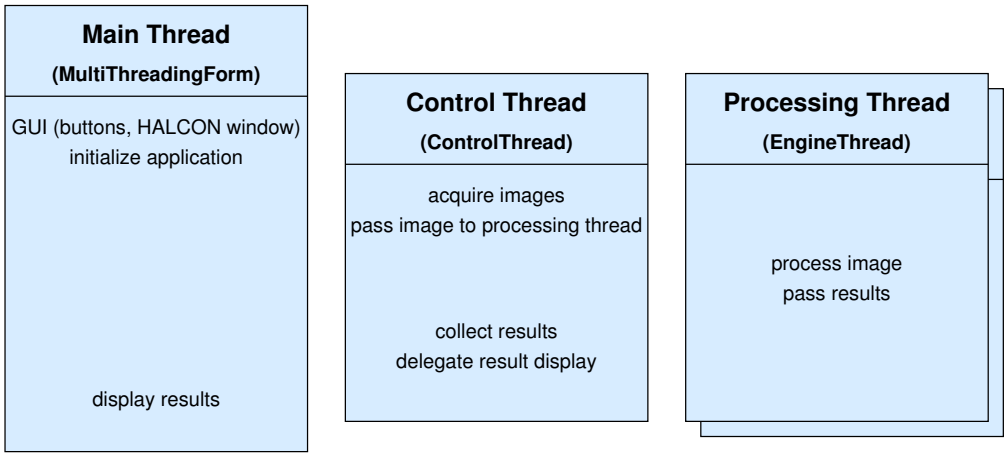


Figure 28.8: Tasks of the threads.

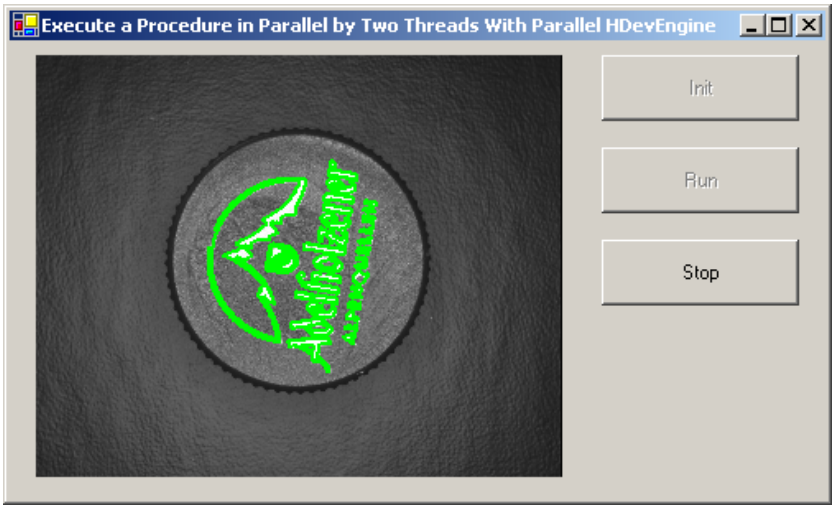


Figure 28.9: Screenshot of the application.

The control thread acquires the images and passes them to the processing threads, which then process the images and pass back the results. The control thread collects the results, but does not display them itself, because all activities in the HALCON window must be performed by the thread that created it, i.e., the main thread.

Now, we take a closer look at the corresponding code. Please note that we do not show all details; in particular, error handling, and termination including memory management are left out.

Initialization

The application is initialized in the event handler of the `Init` button (file: `MultiThreadingForm.cs`).

```
private void InitButton_Click(object sender, System.EventArgs e)
```

Step 1: Switch off automatic operator parallelization

```
  HOperatorSet.SetSystem("parallelize_operators", "false");
```

First, the automatic operator parallelization is switched off, otherwise the two mechanisms (multithreading and operator parallelization) would use more than the available number of cores / processors and thus slow down the application instead of speeding it up (see the style guide in section 2.2.2 on page 20). If you have a system with more than two cores or processors, you can consider to allocate some of them to the automatic operator parallelization as described in section 2.3.1 on page 22.

Step 2: Set external procedure path

Then, we create an instance of `HDevEngine` and set the path for searching the HDevelop procedures (code for constructing the path omitted).

```
  HDevEngine         MyEngine = new HDevEngine();
        string halconExamples, ProcedurePath;
  ...
  MyEngine.SetProcedurePath(ProcedurePath);
```

Step 3: Train the shape model

To initialize the image processing part, we execute an HDevelop procedure that trains the shape model of the caps.

```
  HDevProcedureCall  ProcTrain;

  HDevProcedure Procedure = new HDevProcedure("train_shape_model");
  ProcTrain = new HDevProcedureCall(Procedure);
  ProcTrain.Execute();
```

Step 4: Store the model data

The procedure returns the handle of the shape model and the model contours. We store both in variables of the form so that the processing threads can access them.

```
  public HTuple           ModelID;
  public HXLD             ModelContours;

  ModelID = ProcTrain.GetOutputCtrlParamTuple("ModelID");
  ModelContours = ProcTrain.GetOutputIconicParamXld("ModelContours");
```

Step 5: Create and initialize the processing engines

The actual image processing is encapsulated in the class `EngineThread` (file: `EngineThread.cs`). The main members of this class are a thread and instances of `HDevEngine` and `HDevProcedureCall`. Besides, an `EngineThread` contains variables for accessing the shape model data trained in the main thread and an event that signals that the "engine" is ready for the next image.

```
public class EngineThread
{
  Thread                  WorkerObject = null;
  HDevProcedureCall       ProcCall;
  HTuple                  ModelID;
  HXLD                    ModelContours;
  public AutoResetEvent  EngineIsReady;

  public EngineThread(MultiThreadingForm mainForm)
  {
    ModelID = mainForm.ModelID;
    ModelContours = mainForm.ModelContours;
    EngineIsReady       = new AutoResetEvent(true);
  }
```

The main thread creates and initializes two instances of this class and also stores their events (file: `MultiThreadingForm.cs`).

```
  EngineThread  WorkerEngine1;        // processing thread
  EngineThread  WorkerEngine2;        // processing thread
  AutoResetEvent                              Engine1Ready;
  AutoResetEvent                 Engine2Ready;

  WorkerEngine1 = new EngineThread(this);
  WorkerEngine1.Init();
  Engine1Ready = WorkerEngine1.EngineIsReady;

  WorkerEngine2 = new EngineThread(this);
  WorkerEngine2.Init();
  Engine2Ready = WorkerEngine2.EngineIsReady;
```

An `EngineThread` initializes itself by creating the procedure call for detecting the caps in the images. Because the input parameters of the procedure that concern the shape model are the same for each call, they can be set once in advance (file: `EngineThread.cs`).

```
public void Init()
{
  HDevProcedure Procedure = new HDevProcedure("detect_shape");
  ProcCall = new HDevProcedureCall(Procedure);
  ProcCall.SetInputCtrlParamTuple("ModelID", ModelID);
  ProcCall.SetInputIconicParamObject("ModelContours", ModelContours);
}
```

Step 6: Initialize image acquisition

Finally, we initialize the image acquisition. The handle is stored in a variable of the form, so that the control thread can access it (file: `MultiThreadingForm.cs`).

```
  private HFramegrabber   AcqHandle;

        string ImagePath = halconExamples + "/images/cap_illumination";
  AcqHandle = new HFramegrabber("File", 1, 1, 0, 0, 0, 0, "default", -1,
    "default", -1, "default", ImagePath, "default", -1, -1);
```

Image Processing

When you click the `Run` button, the application starts to process images in a loop.

Step 1: Starting the processing threads and the control thread

First, the main thread starts the processing engines (file: `MultiThreadingForm.cs`).

```
private void RunButton_Click(object sender, System.EventArgs e)
{
  WorkerEngine1.Run();
  WorkerEngine2.Run();
```

The corresponding method creates and starts their thread and sets the "ready" signal (file: `EngineThread.cs`).

```
public void Run()
{
  EngineIsReady.Set();
  WorkerObject = new Thread(new ThreadStart(Process));
  WorkerObject.Start();
}
```

Then, the main thread starts the control thread (file: `MultiThreadingForm.cs`):

```
  ControlThread = new Thread(new ThreadStart(Run));
  ControlThread.Start();
```

Step 2: Triggering the processing threads from the control thread

The control thread's action is contained in the method `Run` (file: `MultiThreadingForm.cs`). As long as the `Stop` is not pressed (please take a look at the project's code for more information), it waits until one of the processing engine is ready.

```
EngineThread  WorkerEngine;         // variable to switch between processing threads

public void Run()
{
  HImage Image;

  while (!StopEventHandle.WaitOne(0, true))
  {
    if (Engine1Ready.WaitOne(0, true))
      WorkerEngine = WorkerEngine1;
    else if (Engine2Ready.WaitOne(0, true))
      WorkerEngine = WorkerEngine2;
    else
      continue;

    Image = AcqHandle.GrabImageAsync(-1);
    WorkerEngine.SetImage(Image);
```

Then, it acquires the next image and passes it to the engine, which stores it in a member variable (file: `EngineThread.cs`).

```
private HImage          InputImage = null;

public void SetImage(HImage Img)
{
  InputImage = Img;
}
```

Step 3: Processing the image

In their action method (`Process`), the processing threads wait for the image to be set (file: `EngineThread.cs`). The actual image processing is performed by the HDevelop procedure, passing the image as input parameter.

```
public void Process()
{
  while (!DelegatedStopEvent.WaitOne(0, true))
  {
    if (InputImage == null)
      continue;

    ProcCall.SetInputIconicParamObject("Image", InputImage);
    ProcCall.Execute();
```

Step 4: Passing the results to the control thread

To pass the results, a class is defined that stores the relevant data: the processed image and the position, orientation, and the contours of the found cap.

```
public class ResultContainer
{
  public HImage  InputImage;
  public HXLD    FoundContours;
  public double  Row;
  public double  Column;
  public double  Angle;
}
```

After executing the procedure, the processing thread accesses its results and stores them in a new instance of the result class ("result container"), together with the processed image.

```
ResultContainer Result;
HTuple          ResultTuple;

Result = new ResultContainer();
Result.InputImage = InputImage;
Result.FoundContours = ProcCall.GetOutputIconicParamXld("ResultObject");
ResultTuple = ProcCall.GetOutputCtrlParamTuple("ResultData");
Result.Row = ResultTuple[0];
Result.Column = ResultTuple[1];
Result.Angle = ResultTuple[2];
```

The processing thread then passes the result container to the control thread by appending it to a list.

```
ResultMutex.WaitOne();
ResultList.Add(Result);
ResultMutex.ReleaseMutex();
```

This list is a member variable of the main thread (file: `MultiThreadingForm.cs`). It is protected by a mutex so that the threads can access it safely.

```
public ArrayList                ResultList;
public Mutex                    ResultDataMutex;

public MultiThreadingForm()
{
  ResultDataMutex   = new Mutex();
  ResultList = new ArrayList();
}
```

The processing threads store references to the list and to the mutex in own member variables (file: `EngineThread.cs`).

```
ArrayList               ResultList;
Mutex                  ResultMutex;

public EngineThread(MultiThreadingForm mainForm)
{
  ResultList            = mainForm.ResultList;
  ResultMutex           = mainForm.ResultDataMutex;
}
```

Step 5: "Ready again"

Finally, the processing thread signals that it is ready for the next image by setting the corresponding event and by setting the input image to `null`.

```
InputImage = null;
this.EngineIsReady.Set();
```

Result Display

Step 1: Checking whether new results are available

Let's return to the action method (`Run`) of the control thread (file: `MultiThreadingForm.cs`). After triggering a processing thread by passing the image to process, it checks whether the result list contains new items.

```
int    Count = -1;

ResultDataMutex.WaitOne();
Count = ResultList.Count;
ResultDataMutex.ReleaseMutex();
```

Step 2: Delegating the display

As described in the style guide for parallel programming in section 2.2.2 on page 20, display activities in a HALCON window should only be performed by the thread that creates the window, which is typically the main thread, i.e., the form. Therefore, the control thread does not perform the display of results itself but delegates it to the main thread (running the form) with the method `Invoke`.

```
for( ;Count > 0;Count--)
  Invoke(DelegatedDisplay);
```

The necessary members are defined by the form.

```
delegate void  FuncDelegate();
FuncDelegate   DelegatedDisplay;

public MultiThreadingForm()
{
  DelegatedDisplay = new FuncDelegate(DisplayResults);
}
```

Step 3: Displaying the results

The actual display is performed by the method `DisplayResults`. Each time it is called, it removes an item from the result list and displays the processed image with the contours of the found cap. Then, it frees the corresponding HALCON-internal memory.

```
public void DisplayResults()
{
  ResultDataMutex.WaitOne();
  Result = (ResultContainer) ResultList[0];
  ResultList.Remove(Result);
  ResultDataMutex.ReleaseMutex();

  Window.ClearWindow();
  Window.DispImage(Result.InputImage);
  Window.DispObj(Result.FoundContours);

  Result.InputImage.Dispose();
  Result.FoundContours.Dispose();
}
```

28.2.5.2 Executing Multiple Procedures in Parallel by Multiple Threads

In contrast to the previous section, the example application `MultiThreadingTwoWindows` presented here executes different HDevelop procedures (tasks) in parallel by two threads. One task is to find bottle caps using shape-based matching, the other to read ECC 200 data codes.

Figure 28.10 shows an overview of the structure of the application. Like the application described in the previous section, it consists of four threads: The main thread (i.e., the form) is in charge of the graphical user interface (GUI), which is depicted in figure 28.9 on page 242. It consists of a HALCON window for the display of results and buttons to initialize, start, and stop the application.

The main thread also initializes the application by creating and initializing the other three threads: two processing threads and the so-called control thread, whichs controls the two processing threads. In contrast to the previous application, here the processing threads initialize the image processing tasks by training the shape model and the data code model, respectively, via HDevelop procedures.

The control thread acquires the images and passes them to the processing threads, which then process the image and pass back the results. The control thread collects the results, but does not display them itself, because all activities in the HALCON window must be performed by the thread that created it, i.e., the main thread. In contrast to the previous application the results of the two tasks are displayed in two separate windows.

Below, we take a closer look at the corresponding code, restricting ourselves, however, to the parts that are diferent to the previous application.

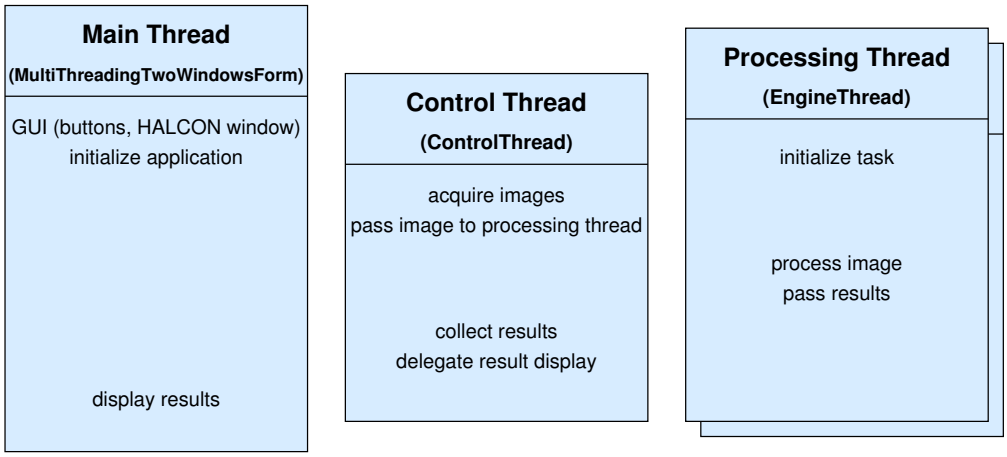


Figure 28.10: Tasks of the threads.

Figure 28.11: Screenshot of the application.

Initialization

As in the previous example, the application is initialized in the event handler of the `Init` button (file: `MultiThreadingTwoWindowsForm.cs`).

Step 1: Create and initialize the processing engines

The processing engines are created and initialized similarly to the previous example, with some exceptions: First, the shape and the data code model are now trained by the processing threads instead of the control thread (see the step below). Secondly, the processing engines now also have a variable that indicates "their" HALCON window (file: `EngineThread.cs`).

```
public class EngineThread
{
  ...
  public int                                    WindowIndex = -1;
  ...
```

The control thread sets this variable after creating the engines (file: `MultiThreadingTwoWindowsForm.cs`).

```
private void InitButton_Click(object sender, System.EventArgs e)
{
  ...
  WorkerEngine1.WindowIndex = 1;
  ...
  WorkerEngine2.WindowIndex = 2;
```

Step 2: Train the shape and data code model

The training of the shape and data code model is now performed by the initialization method of the processing threads, which now has a parameter that specifies the task of the processing thread (file: `MultiThreadingTwoWindowsForm.cs`).

```
  WorkerEngine1.Init("shape");
  ...
  WorkerEngine2.Init("datacode");
```

The HDevelop procedures for training the models and for performing the image processing have similar names for the two tasks, so that their names can be generated automatically (file: `EngineThread.cs`). The task name itself is stored in a variable of the class `EngineThread`.

```
public class EngineThread
{
  HDevProcedureCall       ProcCall;
  string                  Task;
  HTuple                  ModelID;
  HXLD                    ModelContours;
  ...

public void Init(string Task)
{
  string             TrainMethod = "train_" + Task + "_model";
  string             ProcessingMethod = "detect_" + Task;
  HDevProcedureCall  ProcTrain;

  this.Task = Task;
```

Then, the model of the shape or datacode, respectively, is trained by executing the corresponding HDevelop procedure and the returned model data is stored in variables of the class.

```
  HDevProcedure Procedure = new HDevProcedure(TrainMethod);
  ProcTrain = new HDevProcedureCall(Procedure);
  ProcTrain.Execute();
  ModelID = ProcTrain.GetOutputCtrlParamTuple("ModelID");
  if (Task.Equals("shape"))
  {
    ModelContours = ProcTrain.GetOutputIconicParamXld("ModelContours");
  }
```

Step 3: Store the model data

Finally, those input parameters of the image processing procedure that are the same for each call are set (file: `EngineThread.cs`).

```
  HDevProcedure Procedure = new HDevProcedure(ProcessingMethod);
  ProcCall = new HDevProcedureCall(Procedure);
  ProcCall.SetInputCtrlParamTuple("ModelID", ModelID);
  if (Task.Equals("shape"))
  {
    ProcCall.SetInputIconicParamObject("ModelContours", ModelContours);
  }
```

Step 4: Initialize image acquisition

The two image processing tasks are performed in different images, therefore, two image acquisition devices are opened by the main thread (file: `MultiThreadingTwoWindowsForm.cs`, code not shown).

Image Processing

Step 1: Triggering the processing threads

The control thread's action is contained in the method `Run` (file: `MultiThreadingTwoWindowsForm.cs`). As long as the `Stop` is not pressed, it checks whether the processing engines are ready and, if this is the case, acquires and passes images..

```
public void Run()
{
  HImage  Image;

  while (!StopEventHandle.WaitOne(0,true))
  {
    if (Engine1Ready.WaitOne(0,true))
    {
      Image = AcqHandle1.GrabImageAsync(-1);
      WorkerEngine1.SetImage(Image);
    }
    if (Engine2Ready.WaitOne(0,true))
    {
      Image = AcqHandle2.GrabImageAsync(-1);
      WorkerEngine2.SetImage(Image);
    }
```

Step 2: Passing the results to the control thread

The class storing the result data differs significantly from the one in the previous example: It now also contains a variable that indicates the window in which to display the results and a flag that shows whether the processing was successful. Because the processing results differ between the two tasks, they are encapsulated in a tuple (file: `EngineThread.cs`).

```
public class ResultContainer
{
  public int     WindowIndex;   // 1 -> shape, 2 -> datacode
  public HImage  InputImage;
  public HXLD    FoundContours;
  public HTuple  ResultData;
  public bool    DetectionSuccessful;
}
```

After executing the procedure, the processing thread accesses its results and stores them in a new instance of the result container, together with the processed image and the window index.

```
public void Process()
{
  ResultContainer  Result;

  Result = new ResultContainer();
  ...
  Result.InputImage    = InputImage;
  DetectionSuccessful = ProcCall.GetOutputCtrlParamTuple("DetectionSuccessful").S;
  if (DetectionSuccessful.Equals("true"))
  {
    Result.DetectionSuccessful = true;
    Result.FoundContours = ProcCall.GetOutputIconicParamXld("ResultObject");
    Result.ResultData    = ProcCall.GetOutputCtrlParamTuple("ResultData");
  }
  else
  {
    Result.DetectionSuccessful = false;
  }
  Result.WindowIndex = WindowIndex;
```

Result Display

As in the previous example, the display of results is performed by the main thread in the method `ResultDisplay` (file: `MultiThreadingTwoWindowsForm.cs`). The main difference is that the display now is switched between the two HALCON windows, based on the variable in the result container.

```
public void DisplayResults()
{
  HWindow  Window;

  if (Result.WindowIndex == 1)
  {
    Window = Window1;
  }
  else
  {
    Window = Window2;
  }
```

Furthermore, the display method now checks the success of the image processing to avoid accessing non-existing result elements. For both tasks, the resulting contours, i.e., the found shape or data code region, respectively, are displayed. For the data code task, also the read code is displayed.

```
Window.ClearWindow();
Window.DispImage(Result.InputImage);
if (Result.DetectionSuccessful)
{
  Window.DispObj(Result.FoundContours);
  // additional display for data code result: code
  if (Result.WindowIndex == 2)
  {
    Row = (int) Result.ResultData[0].D;
    Col = (int) Result.ResultData[1].D;
    Window.SetTposition(Row,Col);
    Window.WriteString((string) Result.ResultData[2].S);
  }
}
else
{
  Window.SetColor("red");
  Window.SetTposition(20, 20);
  Window.WriteString("Detection failed!");
  Window.SetColor("green");
}
```

Chapter 29

HDevEngine in COM Applications

This chapter explains how to use HDevEngine in Visual Basic applications. Section 29.1 quickly summarizes some basic information about creating HDevEngine applications with Visual Basic 6.0. Section 29.2 then explains how to use HDevEngine by presenting example applications for

- executing an HDevelop program (section 29.2.1),
- executing an (external) HDevelop procedure (section 29.2.2 on page 259),
- implementing display operators (section 29.2.3 on page 263), and
- error handling (section 29.2.4 on page 267).

29.1 Basics

To use HDevEngine in Visual Basic 6.0, you must add the `Halcon/COM library` to your project via the menu item `Project` ▷ `Components` (see also section 20.1 on page 173) and furthermore add the `HDevEngine/COM library` to the project's references via the menu item `Project` ▷ `References`.

HDevEngine XL applications: If you want to use HDevEngine XL, you must register the corresponding DLL `hdevenginexxl.dll` as described in section 20.4 on page 178 for the COM interface of HALCON XL itself.

A short reference of the COM classes for the HDevEngine can be found in section 30.1 on page 269.

29.2 Examples

This section explains how to employ the COM HDevEngine based on example applications for Visual Basic 6.0, which reside in the subdirectories `%HALCONEXAMPLES%\hdevengine\vb6`

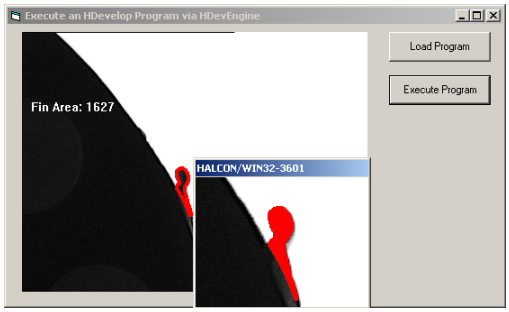


Figure 29.1: Executing an HDevelop program that detects fins on a boundary.

29.2.1 Executing an HDevelop Program

In this section, we explain how to load and execute an HDevelop program with HDevEngine. The code fragments stem from the example application `ExecProgram`, which checks the boundary of a plastic part for fins. Figure 29.1 shows a screenshot of the application; it contains two buttons to load and execute the HDevelop program.

First, we create a global instance of the main HDevEngine class `HDevEngineX`.

```
Dim MyEngine As HDevEngineX
```

Upon loading the form, we store the path to the HDevelop program and the external procedure path in string variables :

```
Dim ProgramPathString As String
Dim ProcPathString As String

Private Sub Form_Load()
  Dim HalconExamples As String

  HalconExamples = Environ("HALCONEXAMPLES")
  If (HalconExamples = "") Then
    HalconExamples = Environ("HALCONROOT") & "\examples"
  End If
  ProgramPathString = HalconExamples & "\hdevengine\hdevelop\fin_detection.hdev"
  ProcPathString = HalconExamples & "\hdevengine\procedures"
```

If the HDevelop program calls external procedures, you must set the external procedure path with the method `SetProcedurePath`:

```
  Call MyEngine.SetProcedurePath(ProcPathString)
```

When you click the button to load the HDevelop program, the method `LoadProgram` is called. Exceptions occurring in the HDevEngine method, e.g., because the file name was not specified correctly, are

handled with the standard Visual Basic error handling mechanism. More information on error handling can be found in section 29.2.4 on page 267.

```
Private Sub LoadBtn_Click()

On Error GoTo errHandler

  Set MyProgram = New HDevProgramX
  Call MyProgram.LoadProgram(ProgramPathString)

  Exit Sub

errHandler:
  Call MsgBox(Err.Description)
End Sub
```

When you click the button to execute the program, the method `Execute` is called:

```
Private Sub ExecuteBtn_Click()

On Error GoTo errHandler

  ' execute program
  Dim ProgramCall As HDevProgramCallX
  Set ProgramCall = MyProgram.CreateCall()
  Call ProgramCall.Execute

  Exit Sub

errHandler:
  Call MsgBox(Err.Description)
End Sub
```

That's all you need to do to execute an HDevelop program. How to display the results is described in section 29.2.3 on page 263.

29.2.2 Executing an External HDevelop Procedure

In this section, we explain how to load and execute an external HDevelop procedure with HDevEngine. The code fragments in the following stem from the example application `ExecExtProc`, which, like the example described in the previous section, checks the boundary of a plastic part for fins. Figure 29.2 shows a screenshot of the application; it contains two buttons to load and execute the HDevelop procedure.

In contrast to the previous example, the result display is programmed explicitly instead of relying on the internal display operators. How to provide your own implementation of the internal display operators is described in section 29.2.3 on page 263.

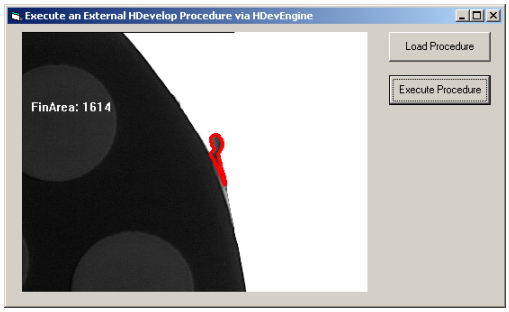


Figure 29.2: Executing an external HDevelop procedure that detects fins on a boundary.

As when executing an HDevelop program, we create a global instance of the main HDevEngine class `HDevEngineX` and set the external procedure path with the method `SetProcedurePath` upon loading the form (code for constructing the path omitted):

```
Dim ProcPathString As String

Dim MyEngine As HDevEngineX

Private Sub Form_Load()

  ...
  Call MyEngine.SetProcedurePath(ProcPathString)

End Sub
```

In contrast to the C++ version of this example application, we want to display the results not in a free-floating graphics, but within the form, i.e, inside an instance of `HWindowXCtrl` (see section 19.1.2.1 on page 165). For calling the HALCON operators, we declare a global variable of the class `HWindowX` for the underlying HALCON window; upon loading the form, we set this variable to the HALCON window in the `HWindowXCtrl` and initialize the window:

```
Dim Window As HWindowX

Private Sub Form_Load()

  Set Window = HXCtrl.HalconWindow

  Call Window.SetPart(0, 0, 575, 767)
  Call Window.SetDraw("margin")
  Call Window.SetLineWidth(4)

End Sub
```

When you click the button `Load`, the HDevelop procedure is loaded with the constructor of the class `HDevProcedureX`, specifying the name of the procedure. Exceptions occurring in the HDevEngine

method, e.g., because the file name or the procedure path was not specified correctly, are handled with the standard Visual Basic error handling mechanism. More information on error handling can be found in section 29.2.4 on page 267.

```
Dim ProcName As String

Private Sub LoadBtn_Click()

On Error GoTo errHandler

  Set MyProcedure = New HDevProcedureX
  Call MyProcedure.LoadProcedureExtern("detect_fin")

  Exit Sub

errHandler:
  Call MsgBox(Err.Description)
End Sub
```

Executing a procedure consists of multiple steps. First, we create an instance of the class `HDevProcedureCallX` and attach it to the loaded procedure:

```
Private Sub ExecuteBtn_Click()

  Dim ProcCall As HDevProcedureCallX

  Set ProcCall = MyProcedure.CreateCall()
```

Before executing it, we load an example image sequence:

```
  Dim FGHandle As HFramegrabberX

  Set FGHandle = New HFramegrabberX
  Call FGHandle.OpenFramegrabber("File", 1, 1, 0, 0, 0, 0, "default", -1, _
                                 "default", -1, "default", "fin.seq", _
                                 "default", -1, -1)
```

Each image should now be processed by the procedure, which has the following signature, i.e., it expects an image as (iconic) input parameter and returns the detected fin region and its area as iconic and control output parameter, respectively:

```
  procedure detect_fin (Image: FinRegion: : FinArea)
```

We pass the image as an input object by storing it in the instance of `HDevProcedureCallX` with the method `SetInputIconicParamObjectByIndex`. Which parameter to set is specified via its index (there is also a method to specify it via its name):

```
  Dim Image As HImageX
  Dim i As Integer

  For i = 0 To 2
    Set Image = FGHandle.GrabImage()
    Call Image.DispObj(Window)
    Call ProcCall.SetInputIconicParamObjectByIndex(1, Image)
```

As as alternative to passing parameters, you can also use **global variables** in HDevEngine (compare the HDevelop User's Guide, section 8.3.1 on page 341). You set the value of a global variable with the methods `SetGlobalIconicVarObject` or `SetGlobalCtrlVarTuple` and query it with the methods `GetGlobalIconicVarObject` and `GetGlobalCtrlVarTuple`.

Now, we execute the procedure with the method `Execute`.

```
    Call ProcCall.Execute
```

If the procedure was executed successfully, we can access its results, i.e., the fin region and its area, with the methods `GetOutputIconicParamObjectByIndex` and `GetOutputCtrlParamTupleByIndex` of the class `HDevProcedureCallX`; again, you can specify the parameter via its index or name. Note that output objects are returned as instances of `HUntypedObjectX` (and not as `HRegionX` in this case), while you can pass input objects as `HImageX`.

```
  Dim FinRegion As HUntypedObjectX
  Dim FinArea As Variant

    Set FinRegion = ProcCall.GetOutputIconicParamObjectByIndex(1)
    FinArea = ProcCall.GetOutputCtrlParamTupleByIndex(1)
```

Finally, we display the results in the raphics window:

```
    Call Image.DispObj(Window)
    Call Window.SetColor("red")
    Call Window.DispObj(FinRegion)
    Call Window.SetColor("white")
    Call Window.SetTposition(150, 20)
    Call Window.WriteString("FinArea: " & FinArea)
  Next

  Exit Sub

errHandler:
  Call MsgBox(Err.Description)
End Sub
```

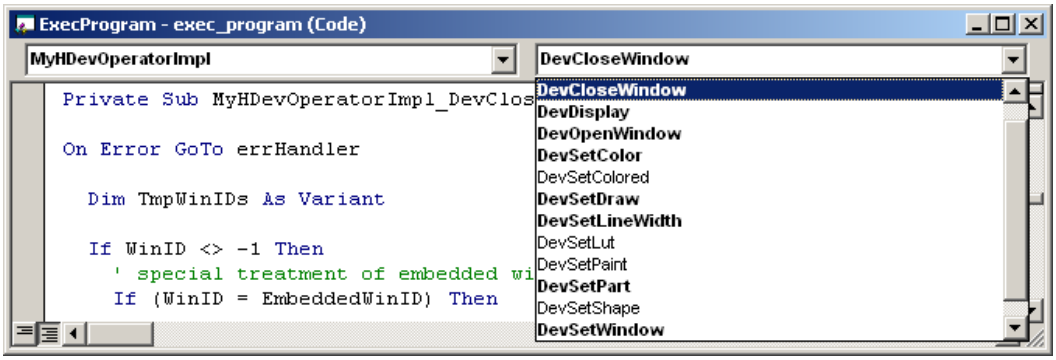


Figure 29.3: Creating event handlers for the display operators.

29.2.3 Display

In this section, we explain how to provide your own implementation of HDevelop's internal display operators. The code fragments in the following stem from the example application `ExecProgram`, which was already discussed in section 29.2.1 on page 258. Please note that **the example implementation is not reentrant**; therefore, it can not be used on a multi-processor or multi-core platform without switching off the automatic parallelization.

In fact, HDevEngine does not provide an implementation of the internal display operators but provides the class `HDevOperatorImplX`, which contains event handlers for all those operators that you can implement yourself. The handlers are called like the object-oriented version of the operators, e.g., `DevDisplay` for `dev_display`, and have the same parameters.

The first step towards the implementation is to declare a global instance of the class `HDevOperatorImplX`. Upon loading the form, we pass this instance to HDevEngine, which then raises the events when the corresponding operator is used in the HDevelop program or procedure.

```
Dim WithEvents MyHDevOperatorImpl As HDevOperatorImplX

Private Sub Form_Load()

  Set MyHDevOperatorImpl = New HDevOperatorImplX
  Call MyEngine.SetHDevOperatorImpl(MyHDevOperatorImpl)
```

To create an event handler for a display operator, select the instance of `HDevOperatorImplX` in the upper left combo box of the form's code window and then select the event handler in the combo box to the right (see figure 29.3).

Compared to the previous example, we want to realize a more complex display: We want to

- display the image and the results in a graphics window that is "embedded" within the form, i.e, inside an instance of `HWindowXCtrl` (see section 19.1.2.1 on page 165) and
- zoom onto the detected fin in a second, free-floating graphics window (see figure 29.1 on page 258).

To switch between multiple windows, we store their window in a tuple and provide a second global variable containing the handle of the active window. However, using window handles instead of instances of the class HWindowX means that we need an instance of the class HOperatorSetX for calling HALCON operators (see section 19.1.2.2 on page 165). As another consequence, the tuple of window handles is declared as a Variant:

```
Dim MyOperatorSet As New HOperatorSetX

Dim WinIDs As Variant
Dim WinID As Variant
```

Furthermore, we provide a variable for the window handle of the HALCON window inside the HWindowXCtrl:

```
Dim EmbeddedWinID As Variant
```

We initialize all these variables upon loading the form. The handle of the active window is set to the handle of the "embedded" window. The tuple is filled with three elements: -1, -1, and the handle of the embedded window.

```
Private Sub Form_Load()

  EmbeddedWinID = HXCtrl.HalconWindow.HalconID
  WinID = EmbeddedWinID

  Call MyOperatorSet.TupleGenConst(3, -1, WinIDs)
  WinIDs(2) = EmbeddedWinID
```

To understand this initialization, we briefly describe how the tuple of window handles is used, the details follow below: The last element of the tuple contains the handle of the active window (-1 if there is none). When a new window is opened with dev_open_window, its handle is appended at the end of the tuple; when dev_close_window is called, the last tuple element is removed. If we would use only one element -1 and then close the last window, the Variant would change from an array to a single value and we would get an error when trying to append a value again. To circumvent this, we use two elements -1.

Now, we show how the management of the windows is realized. dev_open_window is implemented in DevOpenWindow as follows: If there is no active window yet, i.e., the variable storing the handle of the active window is equal to -1, we use the (already opened) "embedded" graphics window and adapt its size to the one specified in the operator call. Otherwise, we open a new window with OpenWindow, passing most of the parameters of dev_open_window and store the returned handle in the variable for the active window handle. We also copy the active window handle into the output parameter of the operator. The window background is set with the operator SetWindowAttr.

Then, we update the tuple of window handles by appending the handle of the active window using TupleConcat. Note that in contrast to, e.g., C++ or HDevelop you cannot use the same variable as input and output parameter, therefore a temporary tuple variable is necessary:

```
Private Sub MyHDevOperatorImpl_DevOpenWindow(ByVal vRow As Variant, _
                                             ByVal vCol As Variant, _
                                             ByVal vWidth As Variant, _
                                             ByVal vHeight As Variant, _
                                             ByVal vBackground As Variant, _
                                             vWindowHandle As Variant)

  Dim TmpWinIDs As Variant
  If WinID = -1 Then
    WinID = HXCtrl.HalconWindow.HalconID
    HXCtrl.Width = vWidth
    HXCtrl.Height = vHeight
  Else
    Call MyOperatorSet.SetWindowAttr("background_color", vBackground)
    Call MyOperatorSet.OpenWindow(vRow, vCol, vWidth, vHeight, 0, _
                                  "visible", "", WinID)
  End If

  vWindowHandle = WinID
  Call MyOperatorSet.TupleConcat(WinIDs, vWindowHandle, TmpWinIDs)
  WinIDs = TmpWinIDs
End Sub
```

dev_close_window is implemented analogously in DevCloseWindow: If there is an active window, it is closed using CloseWindow – if it is not the "embedded" window, in which case it is only cleared using ClearWindow. Then, its handle is removed from the tuple containing all window handles using TupleRemove. The handle of the active window is always stored at the end of the tuple, so that we do not need to "search" for it. Again, we need a temporary tuple variable because we cannot use the same variable as input and output parameter. Finally, the handle of the new active window is stored in the corresponding global variable.

```
Private Sub MyHDevOperatorImpl_DevCloseWindow()

  Dim TmpWinIDs As Variant

  If WinID <> -1 Then
    If (WinID = EmbeddedWinID) Then
      Call MyOperatorSet.ClearWindow(WinID)
    Else
      Call MyOperatorSet.CloseWindow(WinID)
    End If
    Call MyOperatorSet.TupleRemove(WinIDs, UBound(WinIDs), TmpWinIDs)
    WinIDs = TmpWinIDs
    WinID = WinIDs(UBound(WinIDs))
  End If
End Sub
```

The third operator for handling graphics windows, dev_set_window, is implemented as follows in DevSetWindow: As noted above, the handle of the active window is expected to be at the end of the tuple containing all window handles. Therefore, we first search for the specified window handle in

the tuple using TupleFind. If the search was successful, we remove the handle from the tuple using TupleRemove and then append it at the end using TupleConcat. Finally, we store it in the corresponding global variable:

```
Private Sub MyHDevOperatorImpl_DevSetWindow(ByVal vWindowId As Variant)

  Dim Index As Variant
  Dim TmpWinIDs As Variant

  If WinID <> -1 Then
    Call MyOperatorSet.TupleFind(WinIDs, vWindowId, Index)
    If Index <> -1 Then
      Call MyOperatorSet.TupleRemove(WinIDs, Index, TmpWinIDs)
      Call MyOperatorSet.TupleConcat(TmpWinIDs, vWindowId, WinIDs)
      WinID = vWindowId
    Else
      Call MsgBox("DevSetWindow: window handle does not exist!")
    End If
  End If
End Sub
```

Note that this operator is not used in the executed HDevelop program, it is only implemented so that you can use it in your own applications.

The actual display operators can be implemented quite easily. If there is an active window, the methods simply call the corresponding non-internal display operator, e.g., a call to dev_display in the HDevelop program is "redirected" in DevDisplay to DispObj, with the iconic object to display and the handle of the active window as parameters:

```
Private Sub MyHDevOperatorImpl_DevDisplay(ByVal hObj As _
                                          HDevEngineXLib.IHUntypedObjectX)

  If WinID <> -1 Then
    Call MyOperatorSet.DispObj(hObj, WinID)
  End If
End Sub
```

Operators with input control parameters are implemented analogously. For example, dev_set_color is "redirected" in DevSetColor to SetColor:

```
Private Sub MyHDevOperatorImpl_DevSetColor(ByVal vColor As Variant)

  If WinID <> -1 Then
    Call MyOperatorSet.SetColor(WinID, vColor)
  End If
End Sub
```

Figure 29.4: Provoking exceptions in HDevEngine .

29.2.4 Error Handling

In this section, we take a closer look at exceptions in HDevEngine. The code fragments in the following stem from the example application `ErrorHandling`, which provokes different types of exceptions when you press the buttons and "catches" them. Figure 29.4 shows a screenshot of the application.

Note that in contrast to the C++ version, the COM version of HDevEngine does not provide a special class for exceptions. Instead, it uses the standard Visual Basic error handling mechanism and displays the information contained in the C++ class `HDevEngineException` (see section 27.2.4 on page 223) in a message box.

Figure 29.5 displays an exception that occurred because the application tried to load a non-existing HDevelop program. As you can see, only the message contains useful information in this case.

```
Private Sub LoadProgBtn_Click()

On Error GoTo errHandler
  Dim HalconExamples As String
  Dim ProgramPathString As String
  HalconExamples = Environ("HALCONEXAMPLES")
  ProgramPathString = HalconExamples & "\hdevengine\hdevelop\fin_detectionn.hdev"
  Dim Program As HDevProgramX
  Set Program = New HDevProgramX
  Call Program.LoadProgram(ProgramPathString)
  Exit Sub
errHandler:
  Call MsgBox(Err.Description)
End Sub
```

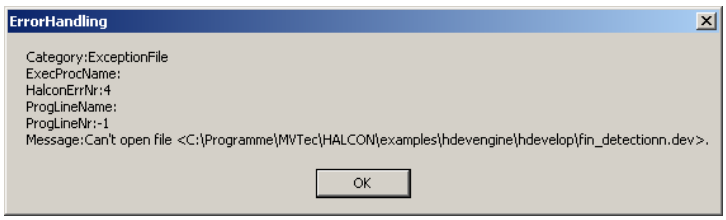


Figure 29.5: Content of the exception if an HDevelop program could not be loaded.

The next exception occurs when executing a procedure in which an input parameter is not initialized:

```
procedure detect_fin_with_error_inpnotinit (Image: FinRegion: : FinArea)
  bin_threshold (NotExistingImage, Dark)
  ...
```

Figure 29.6 displays the content of the exception, which now contains very detailed information about where the error occurred and why.

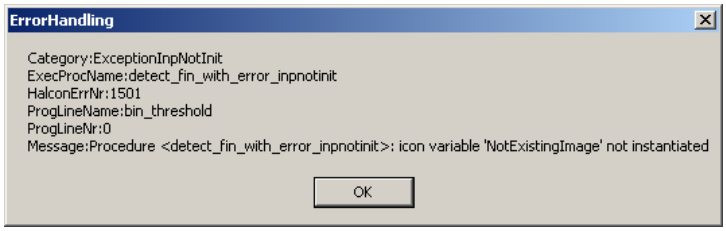


Figure 29.6: Content of the exception if an input parameter was not initialized.

The final exception is provoked by executing a procedure in which the call to the operator `closing_circle` fails because the third parameter is not valid:

```
procedure detect_fin_with_error_call (Image: FinRegion: : FinArea)
  bin_threshold (Image, Dark)
  difference (Image, Dark, Background)
  dev_set_color ('blue')
  dev_display (Background)
  closing_circle (Background, ClosedBackground, -1)
  ...
```

Figure 29.7 shows the content of the exception.

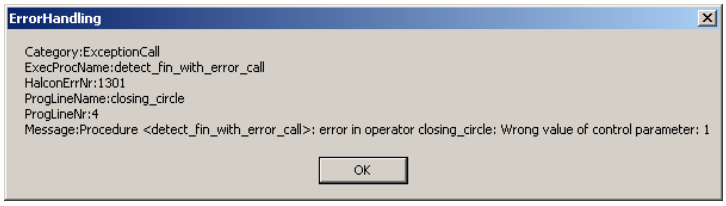


Figure 29.7: Content of the exception if an error occurred in a HALCON operator call.

With the method `UserData` (see section 30.1.7 on page 281), you can also access user exception data that is thrown within an HDevelop program or procedure by the operator `throw` similarly to the operator `dev_get_exception_data`.

Note that you can configure the behavior of HDevEngine when loading programs or procedures that contain invalid lines or unresolved procedure calls with the method `SetEngineAttribute` (see section 30.1.1 on page 270).

Chapter 30

General Information

This chapter contains an overview about the main classes of HDevEngine and their methods (section 30.1) and miscellaneous application tips (section 30.2 on page 282).

30.1 Overview of the Classes

Note in the following, we print only the declaration of the classes for HDevEngine/C++. In the other variants of HDevEngine, the methods and properties have the same names.

30.1.1 HDevEngine

.NET: HDevEngine; COM: HDevEngineX

```
 ****************************************************************************
 ** class HDevEngine
 **==========================================================================
 ** Class for managing global engine settings:
 **  + external procedure path
 **  + implementation of dev_ operators (HDevOperatorImpl)
 **  + Attention: all changes made to one HDevEngine instance all global
 **    for all .dev programs or .dvp procedure that are executed in one
 **    application
 ****************************************************************************
 ****************************************************************************/
class LIntExport HDevEngine
{
public:

  HDevEngine();

  // Via engine attributes the behavior of the engine can be configured
  // currently the following flags are supported:
  //  "ignore_unresolved_lines"  [default: false, 0]
  //     - if set to true (or "true"), program lines that refer to an
  //       unresolved procedure are ignored, i.e., the program or procedure is
  //       executed without the corrupted program line;
  //       this may lead to an unexpected behavior or an error during the
  //       program execution
  //     - as the default an exception is thrown while creating the program or
  //       procedure instance
  //  "ignore_invalid_lines"  [default: false, 0]
  //     - if set to true (or "true"), invalid program lines  are ignored,
  //       i.e., the program or procedure is executed without the corrupted
  //       program line;
  //       this may lead to an unexpected behavior or an error during the
  //       program execution
  //     - as the default an exception is thrown while creating the program or
  //       procedure instance
  //  "ignore_invalid_results" [default: true, 1]
  //     - if set to false (or "false") throw an exception if the accessed
  //       procedure output parameter or program variable is invalid
  //     - the following methods are concerned:
  //         HenProgramCall::GetIconicVarObject()
  //         HenProgramCall::GetCtrlVarTuple()
  //         HenProcedureCall::GetOutputIconicParamObject()
  //         HenProcedureCall::GetOutputCtrlParamTuple()
  //     - as the default an empty region object or an empty tuple is returned
  //       if the object was not set within the program or procedure
  void SetEngineAttribute(const char* name, const Halcon::HTuple& value);
  Halcon::HTuple GetEngineAttribute(const char* name);
```

(continued on next page)

(continued declaration of HDevEngine)

```
  // Set path(s) for external procedures
  //  - several paths can be passed together separating them by ';' or ':'
  //    on Windows or UNIX systems resp.
  //  - NULL removes all procedure paths and unloads all external procedures
  //    (Attention: procedures that are used by programs (HDevProgram) or
  //    procedures (HDevProcedures) remain unchanged until the program or
  //    procedure is reloaded explicitely.  The appropriate calls must be
  //    recreated or reassigned by the reloaded program or procedure.)
  //  - additional calls of SetProcedurePath will remove paths set before
  //    and unload all external procedures
  void SetProcedurePath(const char* path);
  void AddProcedurePath(const char* path);
  // Get names of all available external procedures
  Halcon::HTuple GetProcedureNames() const;
  // Get names of all loaded external procedures
  Halcon::HTuple GetLoadedProcedureNames() const;
  // Unload a specific procedure <proc_name>
  void UnloadProcedure(const char* proc_name);
  // Unload all external procedures
  void UnloadAllProcedures();

  // global variable access
  Halcon::HTuple  GetGlobalIconicVarNames() const;
  Halcon::HTuple  GetGlobalCtrlVarNames()   const;
  // get value of a global vaiable
  Halcon::Hobject GetGlobalIconicVarObject(const char* var_name);
  Halcon::HTuple  GetGlobalCtrlVarTuple(const char* var_name);
  // these method is provided for efficiency:
  // the results are copied directly into the tuple variable provided by
  // the user without additional copying
  void GetGlobalCtrlVarTuple(const char* var_name, Halcon::HTuple* tuple);
  // set global variable
  void SetGlobalIconicVarObject(const char* var_name,
                                const Halcon::Hobject& obj);
  void SetGlobalIconicVarObject(const char* var_name,
                                const Halcon::HObject& obj);
  void SetGlobalIconicVarObject(const char* var_name,
                                const Halcon::HObjectArray& obj);
  void SetGlobalCtrlVarTuple(const char* var_name,
                             const Halcon::HTuple& tuple);


  // Set implementation for HDevelop internal operators
  void SetHDevOperatorImpl(HDevOperatorImplCpp* hdev_op_impl,
                           bool mem_free_intern=true);
};
```

30.1.2 HDevProgram

.NET: HDevProgram; COM: HDevProgramX

```
 ****************************************************************************
 ** class HDevProgram
 **============================================================================
 ** Class for managing HDevelop programs
 ****************************************************************************
class LIntExport HDevProgram
{
public:
  // Create a program from a .dev program file
  HDevProgram(const char* file_name=NULL);

  // Copy constructor
  HDevProgram(const HDevProgram& hdev_prog);
  HDevProgram(const Data& data);

  // Assignment operation
  HDevProgram& operator=(const HDevProgram& hdev_prog);

  // Destructor
  virtual ~HDevProgram();

  // Load a program if not yet done during construction
  void            LoadProgram(const char* file_name);

  // check whether the program was successfully loaded
  bool            IsLoaded() const;

  // Get the program name
  const char*     GetName() const;

  // Get the names of all local and the used external procedures
  Halcon::HTuple  GetUsedProcedureNames()   const;
  Halcon::HTuple  GetLocalProcedureNames()   const;

  // create a program call for execution
  HDevProgramCall CreateCall() const;

  // This is a method provided for convenience:
  // execute the program and return the program call for
  // accessing the variables of the program's main procedure
  HDevProgramCall Execute() const;
```

(continued on next page)

(continued declaration of HDevProgram)

```
  // get some information about the variables of the program's main procedure:
  //  - get the variable names as a tuple
  Halcon::HTuple  GetIconicVarNames() const;
  Halcon::HTuple  GetCtrlVarNames()   const;

  //  - get the number of iconic and control variables
  size_t          GetIconicVarCount() const;
  size_t          GetCtrlVarCount()   const;

  //  - get the names of the variables
  const char*     GetIconicVarName(size_t var_idx) const;
  const char*     GetCtrlVarName(size_t var_idx)   const;
};
```

30.1.3 HDevProgramCall

.NET: HDevProgramCall; COM: HDevProgramCallX

```
 ****************************************************************************
 ** class HDevProgramCall
 **==========================================================================
 ** Class for managing the execution of an HDevelop program
 ****************************************************************************
class LIntExport HDevProgramCall
{
public:
  // Create an empty HDevelop program call instance
  HDevProgramCall();
  // Create an HDevelop program call from a program
  HDevProgramCall(const HDevProgram& prog);
  // Copy constructor
  HDevProgramCall(const HDevProgramCall& hdev_prog_call);
  HDevProgramCall(const Data& data);
  // Assignment operation
  HDevProgramCall& operator=(const HDevProgramCall& hdev_prog_call);
  // Destructor
  virtual ~HDevProgramCall();

  // Get the program
  HDevProgram GetProgram() const;

  // Execute program
  void Execute();

  // Clear program and reset callstack
  //  - this method stops the execution of the program after the current
  //    program line
  void Reset();

  // Get the objects / values of the variables by name or by index
  //   (indices of the variables run from 1 to count)
  Halcon::Hobject GetIconicVarObject(size_t var_idx);
  Halcon::Hobject GetIconicVarObject(const char* var_name);

  Halcon::HTuple  GetCtrlVarTuple(size_t var_idx);
  Halcon::HTuple  GetCtrlVarTuple(const char* var_name);

  // these methods are provided for efficiency:
  // the results are copied directly into the tuple variable provided by
  // the user without additional copying
  void GetCtrlVarTuple(size_t var_idx, Halcon::HTuple* tuple);
  void GetCtrlVarTuple(const char* var_name, Halcon::HTuple* tuple);
};
```

30.1.4 HDevProcedure

.NET: HDevProcedure; COM: HDevProcedureX

```
 ****************************************************************************
 ** class HDevProcedure
 **==========================================================================
 ** Class for managing HDevelop procedures
 ****************************************************************************
class  LIntExport HDevProcedure
{
public:
  // Create HDevelop procedure from external or local procedure
  HDevProcedure(const char* proc_name=NULL);
  HDevProcedure(const char* prog_name, const char* proc_name);
  HDevProcedure(const HDevProgram& prog, const char* proc_name);

  // Copy constructor
  HDevProcedure(const HDevProcedure& hdev_proc);
  HDevProcedure(const Data& data);
  // Assignment operation
  HDevProcedure& operator=(const HDevProcedure& proc);
  // Destructor
  ~HDevProcedure();

  // Load a procedure if not yet done during construction
  void         LoadProcedure(const char* file_name);
  void         LoadProcedure(const char* prog_name, const char* proc_name);
  void         LoadProcedure(const HDevProgram& prog, const char* proc_name);

  // Check whether the procedure was successfully loaded
  bool         IsLoaded() const;

  // Get the name of the procedure
  const char*  GetName() const;

  // Get the short description of the procedure
  const char*  GetShortDescription() const;

  // Get all refered procedures
  Halcon::HTuple  GetUsedProcedureNames() const;

  // Create a program call for execution
  HDevProcedureCall CreateCall() const;
```

(continued on next page)

(continued declaration of HDevProcedure)

```
  // Get name of input/output object/control parameters
  Halcon::HTuple GetInputIconicParamNames()  const;
  Halcon::HTuple GetOutputIconicParamNames() const;
  Halcon::HTuple GetInputCtrlParamNames()    const;
  Halcon::HTuple GetOutputCtrlParamNames()   const;

  // Get number of input/output object/control parameters
  int            GetInputIconicParamCount()  const;
  int            GetOutputIconicParamCount() const;
  int            GetInputCtrlParamCount()    const;
  int            GetOutputCtrlParamCount()   const;

  // Get name of input/output object/control parameters
  const char*    GetInputIconicParamName(int par_idx)  const;
  const char*    GetOutputIconicParamName(int par_idx) const;
  const char*    GetInputCtrlParamName(int par_idx)    const;
  const char*    GetOutputCtrlParamName(int par_idx)   const;
};
```

30.1.5 HDevProcedureCall

.NET: HDevProcedureCall; COM: HDevProcedureCallX

```
 ****************************************************************************
 ** class HDevProcedureCall
 **==========================================================================
 ** Class for executing an HDevelop procedure and managing the parameter
 ** values
 ****************************************************************************
 ****************************************************************************/
class  LIntExport HDevProcedureCall
{
  HDEV_PD;

public:

  // Create an empty HDevelop procedure call instance
  HDevProcedureCall();
  // Create HDevelop procedure call instance
  HDevProcedureCall(const HDevProcedure& hdev_proc);
  // Copy constructor
  HDevProcedureCall(const HDevProcedureCall& hdev_proc_call);
  HDevProcedureCall(const Data& data);
  // Assignment operation
  HDevProcedureCall& operator=(const HDevProcedureCall& hdev_proc_call);
  // Destructor
  ~HDevProcedureCall();

  // Get the procedure
  HDevProcedure GetProcedure() const;

  // Execute program
  void Execute();

  // Clear program and reset callstack
  //  - this method stops the execution of the program after the current
  //    program line
  void Reset();
```

(continued on next page)

(continued declaration of HDevProcedureCall)

```
  // Set input object/control parameter
  void SetInputIconicParamObject(int par_idx, const Halcon::Hobject& obj);
  void SetInputIconicParamObject(int par_idx, const Halcon::HObject& obj);
  void SetInputIconicParamObject(int par_idx, const Halcon::HObjectArray& obj);
  void SetInputIconicParamObject(const char* par_name,
                                 const Halcon::Hobject& obj);
  void SetInputIconicParamObject(const char* par_name,
                                 const Halcon::HObject& obj);
  void SetInputIconicParamObject(const char* par_name,
                                 const Halcon::HObjectArray& obj);
  void SetInputCtrlParamTuple(int par_idx, const Halcon::HTuple& tuple);
  void SetInputCtrlParamTuple(const char* par_name,
                              const Halcon::HTuple& tuple);

  // Get the objects / values of the parameters by name or by index
  //   (indices of the variables run from 1 to count)
  Halcon::Hobject GetOutputIconicParamObject(int par_idx)          const;
  Halcon::Hobject GetOutputIconicParamObject(const char* par_name) const;
  Halcon::HTuple  GetOutputCtrlParamTuple(int par_idx)             const;
  Halcon::HTuple  GetOutputCtrlParamTuple(const char* par_name)    const;

  // These methods are provided for efficiency:
  // the results are copied directly into the tuple variable provided by
  // the user without additional copying
  void GetOutputCtrlParamTuple(int par_idx, Halcon::HTuple* tuple) const;
  void GetOutputCtrlParamTuple(const char* par_name,
                               Halcon::HTuple* tuple)              const;
};
```

Note that HDevEngine/.NET provides additional methods that return iconic output parameters of a procedure call in the corresponding class (GetOutputIconicParamImage, GetOutputIconicParamRegion, GetOutputIconicParamXld).

Note that in COM methods cannot be overloaded. Therefore, HDevEngine/COM provides two separate methods in such a case, in particular

- SetInputIconicParamObjectByIndex/ SetInputIconicParamObjectByName,
- SetInputCtrlParamTupleByIndex/ SetInputCtrlParamTupleByName,
- GetOutputIconicParamObjectByIndex/ GetOutputIconicParamObjectByName, and
- GetOutputCtrlParamTupleByIndex/ GetOutputCtrlParamTupleByName

to set and access procedure parameters.

30.1.6 HDevOperatorImplCpp

.NET: IHDevOperators; COM: HDevOperatorImplX

```
 ***************************************************************************
 ** class HDevOperatorImplCpp
 **=========================================================================
 ** Class for the implemention of HDevelop internal operators
 ***************************************************************************
class LIntExport HDevOperatorImplCpp
{
public:
  HDevOperatorImplCpp();
  // Copy constructor
  HDevOperatorImplCpp(const HDevOperatorImplCpp& hdev_op_impl);
  HDevOperatorImplCpp(const Data& data);
  // Assignment operation
  HDevOperatorImplCpp& operator=(const HDevOperatorImplCpp& hdev_op_impl);
  // Destructor
  virtual ~HDevOperatorImplCpp();

  virtual int DevClearWindow();
  virtual int DevCloseWindow();
  virtual int DevSetWindow(const Halcon::HTuple& win_id);
  virtual int DevDisplay(const Halcon::Hobject& obj);
  virtual int DevSetWindowExtents(const Halcon::HTuple& row,
                                  const Halcon::HTuple& col,
                                  const Halcon::HTuple& width,
                                  const Halcon::HTuple& height);
  virtual int DevSetDraw(const Halcon::HTuple& draw);
  virtual int DevSetShape(const Halcon::HTuple& shape);
  virtual int DevSetColored(const Halcon::HTuple& colored);
  virtual int DevSetColor(const Halcon::HTuple& color);
  virtual int DevSetLut(const Halcon::HTuple& lut);
  virtual int DevSetPaint(const Halcon::HTuple& paint);
  virtual int DevSetPart(const Halcon::HTuple& row1,
                         const Halcon::HTuple& col1,
                         const Halcon::HTuple& row2,
                         const Halcon::HTuple& col2);
  virtual int DevSetLineWidth(const Halcon::HTuple& width);
  virtual int DevOpenWindow(const Halcon::HTuple& row,
                            const Halcon::HTuple& col,
                            const Halcon::HTuple& width,
                            const Halcon::HTuple& height,
                            const Halcon::HTuple& background,
                            Halcon::HTuple* win_id);
};
```

30.1.7 HDevEngineException

.NET: HDevEngineException; COM: –

```
 ****************************************************************************
 ** class HDevEngineException
 **==========================================================================
 ** Class for HDevelop engine exceptions
 ****************************************************************************
class LIntExport HDevEngineException
{
public:
  // Exception categories
  enum  ExceptionCategory
  {
    Exception,            // Generic
    ExceptionInpNotInit,  // Error input parameters not initialized
    ExceptionCall,        // Error HALCON or HDevelop operator call
    ExceptionFile         // Error opening or reading HDevelop file
  };

  // Create HDevelop engine exception
  HDevEngineException(const char* message,
                      ExceptionCategory category=Exception,
                      const char* exec_proc_name="",
                      int prog_line_num=-1,
                      const char* prog_line_name="",
                      Herror h_err_nr=H_MSG_VOID,
                      const Halcon::HTuple& user_data=Halcon::HTuple());
  HDevEngineException(const HDevEngineException& exc);
  HDevEngineException(const Data& data);
  HDevEngineException& operator = (const HDevEngineException& exc);
  virtual ~HDevEngineException();

  // Error text
  const char*            Message()           const;
  // Category of exception
  ExceptionCategory      Category()          const;
  const char*            CategoryText()      const;
  // Name of executed procedure
  const char*            ExecProcedureName() const;
  // Number of executed procedure or operator program line
  int                    ProgLineNum()       const;
  // Name of executed procedure or operator program line
  const char*            ProgLineName()      const;
  // HALCON error number
  Herror                 HalconErrNum()      const;

  Halcon::HTuple         UserData()          const;
  void                   UserData(Halcon::HTuple& user_Data) const;
};
```

30.2 Tips and Tricks

30.2.1 Troubleshooting

Executed program or procedure raises exception for display operators like set_tposition when not using implementation of display operators

If you are not using an implementation of HDevelop's internal display operators (dev_*), calls to these operators in the executed HDevelop program or procedure are simply ignored. However, if the program or procedure contains other, "external" display operators like set_tposition or write_string, which need a window handle as input parameter, the program / procedure will raise an exception at this operator if the window handle has not been instantiated.

Typically, this problem will not arise when executing programs, because you will in most cases use an implementation of the display operators. When executing procedures, we recommend to leave out the external display operators that use window handles. If this is not possible, you could place them in a separate procedure and use the implementation of display operators for just this procedure. Alternatively, initialize the window handle with a value like -1 and test it before executing the external display operators.

External procedures cannot call local procedures

Note that local procedures can call external procedures but not the other way round.

30.2.2 Loading and Unloading Procedures

In most applications there is no need to delete loaded HDevelop procedures explicitly using UnloadProcedure. A reason might be to free memory.

Please note that when creating a procedure with the class HDevProcedure, the procedure is loaded together with all the procedures it uses. In contrast, UnloadProcedure deletes only the specified procedure. To delete the automatically loaded procedures, you can query their names using GetLoadedProcedureNames and then delete them (if you are sure that they are not used by another loaded procedure!), or you can use UnloadAllProcedures to unload all external procedures.

As an alternative, you can reset the external procedure paths by passing an empty string to SetProcedurePath or call UnloadAllProcedures.

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